THE

YOUNG ASTRONOMER,

OR,

THE FACTS DEVELOPED

BY

MODERN ASTRONOMY,

COLLECTED FOR

THE USE OF SCHOOLS

AND

THE GENERAL READER.

BY JOHN S. C. ABBOTT,

AUTHOR OF "MOTHER AT HOME," AND "CHILD AT HOME."

NEW YORK:
SAXTON AND MILES,
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Deposited in the Clerk's Office for the So. Dist. of New York, June 6. 1846.

JENKINS, STEREOTYPER AND PRINTER,
114 Nassau street.

PREFACE.

Most treatises upon Astronomy contain much which is quite unintelligible to those who have not passed through a regular course of mathematical studies. It is, however, very desirable that all the youth in our schools should be familiar with those simple yet sublime facts, which have been developed by this science. To present these facts in language which can be comprehended by every good understanding in our common schools and academies, is the object of this work. It is hoped that these pages may incite a deeper interest in the study of this most noble of all the sciences; that it may disseminate widely, in the popular mind, an acquaintance with those truths which are so eminently calculated to elevate the understanding, and to ennoble the heart; and that many may be induced to prosecute the study into those higher regions of mathematical inquiries, which can call into requisition all the energies of a Newton and a Herschel.

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THE

YOUNG ASTRONOMER.

CHAPTER I.

GENERAL VIEW OF THE SOLAR SYSTEM.

THE SUN.

THE science of Astronomy treats of the motions, magnitudes and distances of the heavenly bodies. From the earliest ages of the world the stars have attracted attention; and shepherds on the hillside, as they watched their flocks by night, and philosophers, on their housetops, have observed their apparent motions, counted their numbers, and endeavored to arrange them into classes or fanciful groups, which they called Constellations.

The theory of Astronomy which has almost universally prevailed until within the last four hundred years, is called the Ptolemaic theory. It receives this name from Ptolemy, its most distinguished advocate. Ptolemy lived about two hundred years after the birth

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Of what does Astronomy treat? How long has Astronomy engaged attention? Who have particularly watched the stars? What are groups of stars called? What theory of Astronomy has formerly prevailed? Why is the Ptolemaic theory so called? When did Ptolemy live?

of Christ. The Ptolemaic theory of Astronomy places the Earth in the centre of the universe, and supposes the Sun and the stars to revolve around it.

The theory now universally received, is called the Copernican theory. Copernicus, who established this theory, lived about four hundred years ago. The Copernican theory is, that the Sun is the centre, around which the Earth, and all the planets of the Solar system revolve. It also supposes that the fixed stars are suns and centres, around which other systems revolve.

The Solar system includes the Sun, and all the heavenly bodies which revolve around it. Those bodies which, revolving around the Sun, shine, not by their own, but by reflected light, are called planets. The innumerable other glittering bodies which twinkle in the firmament, and which are immovable in their relative position, and which shine not by reflected, but by their own light, are called fixed stars. The *planets* can be usually distinguished from the *fixed stars* by their mild, moon-like light, while the stars shine with a more intense and twinkling lustre. The planets are supposed to be worlds, somewhat resembling our own. The fixed stars are considered as suns. They are at such an immense distance, that even the telescope does not reveal to our view the revolving worlds to which they dispense light and heat.

What is the Ptolemaic theory? What is the present theory of Astronomy called? Who established this theory? When did he live? What is the Copernican theory? What does the Solar system include? What are planets? What are fixed stars? How can the planets be distinguished? How can the stars be distinguished? What are the planets supposed to be? What are the stars supposed to be? Why do we not see the planets which are supposed to revolve around the stars?

There are connected with the Solar system, besides the planets, vast bodies, called *comets*, of whose physical structure and constitution, comparatively little is known. They pass around the Sun, and then disappear in the depths of space, and after the lapse, perhaps, of many centuries, reappear, alarming the ignorant by their portentous aspect in the sky. It has been supposed that the comets may connect two or more systems together, by revolving around the suns which are the centres of those systems.

It is difficult from diagrams to attain any very correct conception of the Solar system. The following striking illustration, of the proportionate magnitudes and distances of the bodies composing the Solar system, has been given by Herschel. Let the Sun be represented by a globe two feet in diameter. At eighty-two feet distant put down a grain of mustard seed, and you have the size and place of the planet Mercury. At the distance of one hundred and forty-two feet lay down a pea, and it will represent Venus. Two hundred and fifteen feet from the central globe place another pea of about the same size, and it will represent the Earth. At the distance of three hundred and

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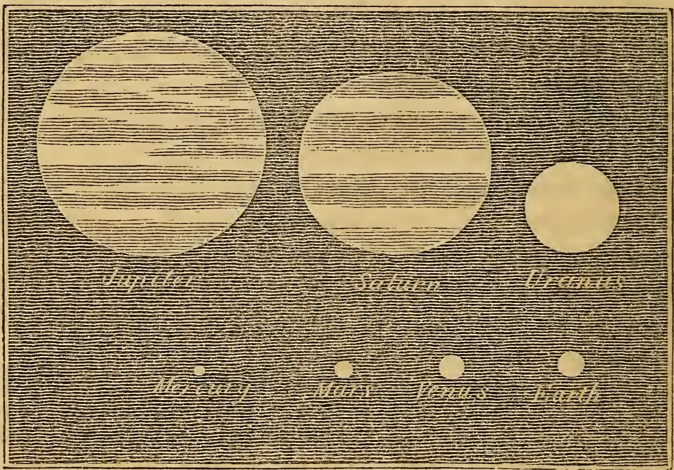
What bodies besides planets are connected with the Solar system? What is said of their physical structure and constitution? After passing around the Sun where do they go? What has it been supposed that comets connect? Do diagrams give a correct idea of the Solar system? Who has given a striking illustration of the bodies composing this system? By what would Herschel represent the Sun? At what distance would he place Mercury? What would represent its proportionate magnitude? At what distance would he place Venus? What would represent the proportionate magnitude of Venus? At what distance would he place the Earth? What would represent the proportionate magnitude of the Earth?

twenty-seven feet place a pin's head, and it will represent the planet Mars. About five hundred feet from the Sun, place five of the smallest grains of sand, to represent Vesta, Astrea, Juno, Ceres and Pallas, which are called the Asteroids. At a quarter of a mile from the globe which represents the Sun, place an orange of a middle size, and it will represent Jupiter. An orange a little smaller, two-fifths of a mile distant, will represent Saturn. And Herschel would be represented by a cherry, three quarters of a mile distant. It will at once be perceived that by or-

COMPARATIVE MAGNITUDES OF THE PLANETS.



By what would Mars be represented! At what distance? Where would the Asteroids be placed? By what would they be represented? At what distance should Jupiter be placed? By what should it be represented? Where should Saturn be placed? What would represent its size? What would represent the size of Herschel? At what distance should it be placed?

dinary orreries and diagrams, but a feeble idea can be communicated of the comparative magnitude and distances of the worlds which compose the Solar system. The accompanying diagram may, however, give the reader a general idea of the relative position of the planets, and may perhaps aid the mind in forming correct conceptions.

RELATIVE POSITION OF THE PLANETS.

THE SOLAR SYSTEM.

THE SUN.

The Sun is the centre of the Solar system. For many ages that vast luminary was supposed to be a globe of liquid fire. But now the body of the Sun is ascertained to be a solid and dark mass, of stupendous magnitude; somewhat resembling in its aspect the globe on which we live. A luminous atmosphere, many distinguished Astronomers have conjectured, of vast extent, and of intense brilliancy, surrounds the solid body of the Sun, and throws out its rays of light and heat to the most distant of the planetary worlds. In this atmosphere of dazzling splendor, there are frequently seen openings or cavities, through which is distinctly visible the dark mass of the interior globe. It is impossible to ascertain what is the precise nature of this luminous substance, of such intense energy, which envelopes the Sun. Many have supposed it to be analogous to the electric fluid which gleams from the thunder clouds; and that vast accumulations of this subtle and inexplicable element surround the Sun. These electric clouds, or luminous vapors, are supposed, by Herschel, to be between two or three thousand

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What body is the centre of the Solar system? What was the Sun formerly supposed to be? What is the Sun now ascertained to be? From whence does the light and heat of the Sun proceed? What is frequently seen in this atmosphere? What is the precise nature of this luminous substance? To what have many supposed it to be analogous? How thick are these luminous clouds?

miles in thickness. This discovery of modern science beautifully illustrates the Mosaic account of the creation. It is there said that light was created before the Sun itself. This now appears reasonable. For *light* or this luminous atmosphere was first created. The Sun was then appointed the great *light-bearer*, around which the luminous substance was gathered. Thus has the advancement of science removed a difficulty in the account of the creation, which in the days of ignorance perplexed the mind.

The cavities which are seen in these luminous clouds, appear like dark spots on the surface of the Sun. Some are found to be of the most enormous magnitude. The smallest which are visible to us, are not less than five hundred miles in diameter. Some have been ascertained to be more than forty thousand miles in length, and sixteen thousand in breadth. Upon such a spot as this, ten globes, as large as the earth, might be placed. These spots never continue for a long time of the same figure; but are subject to numerous and rapid changes. It is seldom that any one spot continues for more than six weeks. The luminous clouds seem to close together, and as one spot disappears, others are seen in other places. Some occurrences seem to lead to the opinion that when there are many spots observed

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What does the discovery of these luminous clouds illustrate? What difficulty has appeared in the Mosaic account of the creation? How does this discovery remove the difficulty? How do the cavities in these luminous clouds appear? Are they large or small? What is the size of the smallest? What is the size of the largest? What illustration is given of the size of this largest cavity? How long do these spots generally continue? Describe the mode of their change? What opinion has been drawn respecting the influence of these spots upon temperature?

on the surface of the Sun, the heat of the Sun is diminished. But upon this subject not enough facts have yet been collected to lead to any positive conclusion.

Beneath this atmosphere of such ineffable splendor, and between it and the sun, there is observed to be a second atmosphere, or stratum of clouds, of inferior brightness. It is supposed that this cloudy stratum is intended as a screen, to protect the inhabitants of the Sun from the too excessive light and heat of the electric or luminous atmosphere which surrounds that stupendous globe. Thus there may be a happy population rejoicing in the valleys and along the hillsides of that magnificent mansion of our God. They may enjoy the luxury of an ever genial clime. They may dwell in attempered rays of heat and light, which never dazzle and never burn.

The magnitude of the Sun surpasses all powers of human conception. The Sun is about nine hundred thousand miles in diameter. It is three millions of miles in circumference. But these vast numbers convey no distinct conception to the human mind. The imagination may, perhaps, be slightly aided by the following illustrations of the Sun's magnitude.

1. Were the Sun placed where the Earth now is, its solid contents would fill the whole space enclosed by the orbit of the Moon; and it would extend two hun-

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Why is there no positive conclusion upon this subject? What is interposed between these luminous clouds and the surface of the Sun? What is supposed to be the object of this screen? What inference is drawn from this fact? What is the diameter of the Sun? Do these numbers convey any distinct idea to the mind? How may the imagination be aided? What is the first illustration of the magnitude of the Sun?

dred thousand miles in every direction beyond the orbit of the Moon. The whole of this almost measureless region would be filled with the solid contents of that stupendous orb.

2. Were a person to travel over thirty square miles of the Sun every day, it would require more than two hundred and twenty millions of years to survey its surface.

3. Were the Sun a hollow ball, it would contain thirteen hundred thousand globes as large as the Earth.

4. If the surface of the Sun were peopled with inhabitants, it would sustain as large a population as could live on eight hundred and fifty thousand such globes as the Earth.

Notwithstanding these illustrations, the mind in vain endeavors to attain a conception of the grandeur of this majestic globe. Even angelic powers may be exhausted in the endeavor to grasp the grand idea. It is considered as a demonstrated truth, that the surface of the Sun is diversified with towering mountains and widespread vales. And upon these hillsides and verdant savannahs, where no night ever darkens the sky, and no winter ever chills the flowers or the fruit, there may be beauty and luxuriance of vegetation, such as Eden never witnessed. There is probably no night upon the Sun, for it is enveloped, at all times, in a blaze of splendor. There is probably no winter upon the Sun, for that atmosphere, which is the fountain of heat,

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What is the second illustration of the magnitude of the Sun? What the third? What the fourth? How is the surface of the Sun diversified? Is there any night upon the Sun? Why not? Is there any winter there? Why not?

exists equally at the equator and at the poles. May we not hope that a sinless population crowds those blissful vales. If there the clamor of selfishness and of oppression is unknown, and every heart throbs with love for God, and love for its fellow, surely this realm, in all its amplitude, is worthy to be ranked among those heavenly mansions, which our Saviour has gone to prepare for his followers. As one star differeth from another star in glory, and as there are different degrees of rank and elevation among the intelligences whom God has formed, it is by no means improbable that the Sun may be peopled by a loftier race than man; by a race unsusceptible of fatigue, and living in the vigor of eternal youth. It is one of the peculiarities of the future home of redeemed man, that "there is no night there."

The Sun has a revolution upon its own axis. It revolves once in about twenty-five days. This rotation was discovered by the motion of spots on the surface or disk of the Sun. A dark spot will frequently appear on the eastern edge of the Sun, and move gradually along, day after day, till it arrives at the western edge. Then disappearing, in the course of about twelve days it will again be seen manifesting itself upon the eastern edge. The regular rotation of these spots, proves that the Sun is a globe; and that it revolves upon its own axis from east to west, in about

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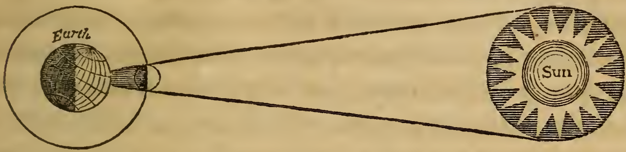
What pleasing hope may we indulge? What supposition is not improbable? What motion has the Sun? In what time does the Sun revolve upon its axis? How was this rotation discovered? Describe the movement of these spots? What does the regular rotation of these spots prove?

twenty-five days. The Sun is eclipsed when the Moon, passing between the Earth and the Sun, casts its shadow on the Earth, as is seen in the accompanying diagram.



Besides the revolution of the Sun upon its own axis, Herschel conjectures that the Sun, carrying with it all the planetary system, is circling around some distant and unknown centre. What that centre is no one can tell. In what depths of space it is buried, no one can imagine. But the idea is sublime in the highest degree, that the stupendous Sun itself, with all its retinue of revolving worlds, is gliding through the depths of space in an immeasurable orbit. Probably thousands of years are occupied, in traversing this limitless pathway. Herschel was led to this conjecture, by observing that the stars, in one quarter of the heavens, appear to be very gradually approaching each other, while in an opposite quarter the stars as gradually seem to recede. This apparent motion, almost imperceptible as it is, would be caused by an actual movement of the Sun towards the stars, which seem to be receding from each other.

When is the Sun eclipsed? What motion has the Sun besides a revolution upon its axis? What is the centre around which the Sun revolves? What length of time is probably occupied by the Sun in traversing its circuit? What led Herschel to the conclusion that the Sun revolves around some distant centre? What would cause the stars apparently to recede from each other?

The distance of the Sun from the Earth is estimated to be seventy-five millions of miles. A carriage, traveling at the rate of twenty miles an hour, would occupy more than five hundred years in traversing this distance. Many persons are incredulous, respecting the ability of Astronomers to measure the vast distances interposed between the heavenly bodies and the Earth. But the principles upon which this measurement is conducted are perfectly simple, and the results demonstrably accurate. Any civil engineer can measure the height of a distant mountain, or a fortress, though he may not be able to climb the mountain, and the fortress may be inaccessible. He simply measures a base line, upon the ground on which he stands. From the two extremities of this line, he takes the bearing of the object; that is the angle which a line running to the distant object makes with the base line. Then from the most simple principles of geometry and arithmetic, he calculates the distance of the object. It is in this way that most of the surveys on Earth are taken. Neither the magnitude nor the distance of the object under observation increases the difficulty of the measurement.

In measuring the distance of the heavenly bodies, we take for a base line the diameter of the Earth, which is eight thousand miles. And when the distance

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What is the distance of the Sun from the Earth? How long would it take a carriage to traverse this distance at the rate of twenty miles an hour? What is said of the accuracy of astronomical measurements? How does a civil engineer measure heights which are inaccessible? What does not add to the difficulty of measurement? In measuring the distance of heavenly bodies what is taken as the base line? What is the diameter of the Earth?

of the object observed is such that even that vast line dwindles, as it were, into a point, we take for a base line the diameter of the Earth's orbit. This line is nearly two hundred millions of miles in length. To pass over it, in a rail-car travelling at the rate of thirty miles an hour, would require nearly eight thousand years. The more distant the object is, the larger, of course, is the angle of its bearing with the base line. If the object be so distant that there is no perceptible angle at all, of its bearing with the base line, the distance of the object cannot be measured. Under such circumstances, it is certain that the object cannot be within certain limits, but its positive distance cannot be ascertained. And such is the fact in reference to nearly all the stars glittering in the firmament. With so stupendous a base line as the diameter of the Earth's orbit, no perceptible change in their bearing can be perceived from either extremity.

The Earth is farther from the Sun when in one part of its orbit than when in another part. This results from the fact that the orbit in which the Earth revolves is not a perfect circle. Its diameter in one direction is more than three millions of miles longer than in the

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When the diameter of the Earth is not sufficient what is taken? What is the length of the diameter of the Earth's orbit? How long would it take a carriage, at the rate of thirty miles an hour, to pass over this line? What influence has the distance of an object upon the angle of its bearing with a base line? When can the distance of an object not be measured? What is certain in such a case? What is the fact in reference to the fixed stars generally? With what base line is it endeavored to measure their distance? Is the Earth always equally distant from the Sun? Why is it not always equally near the Sun? How much difference is there in the diameters of its orbits?

other. Such a figure is called an ellipse. The difference between the longest and the shortest diameter is called the eccentricity of the ellipse. The Earth is nearest the Sun in winter, and farthest from it in summer. In summer, however, the rays of the Sun fall nearly perpendicularly upon us, causing intense heat. In the winter the rays fall upon us obliquely, and hence the severity of the cold.

Almost every motion which takes place on the surface of the Earth is influenced by the rays of the Sun.

1. All winds are caused by the heat of the Sun promoting currents of air in the atmosphere. Particles of air heated intensely in one place by the rays of the Sun, rapidly rise, while the surrounding atmosphere rushes in to fill the vacant space. Hence gentle zephyrs, tornadoes and whirlwinds.

2. The whole vegetable kingdom is dependent for life and growth upon the light and heat of the Sun's rays.

3. The heat of the Sun raises, by evaporation, the water of the ocean, circulates it in vapor over the land, and then letting it fall in showers, creates all the springs and rivers.

4. The crumbling of the mountains even is caused by the abrasion of the wind and rain, and the change of the seasons which the Sun produces.

What is such a figure called? What is meant by the eccentricity of an ellipse? When is the Earth nearest the Sun? When farthest from it? Why have we intense heat in summer? Why cold in winter? By what are most of the motions which take place on the surface of the Earth influenced? How are winds caused? How does the heat of the Sun promote currents in the atmosphere? Upon what does the vegetable kingdom depend? How are springs and rivers caused? How is the crumbling of mountains caused.

It has long been a question of much interest, whether the Sun is probably inhabited. Upon this question Astronomers are not yet fully agreed. The following arguments have been adduced by the most eminent Astronomers, in favor of the Sun being peopled. They are sufficient to lead most minds to the conclusion that probably countless myriads of happy beings are rejoicing amid the splendor of that vast orb.

1. The Sun is evidently a solid globe of mountains and valleys, and thus adapted to be the home of intelligent creatures.

2. It is contrary to analogy to suppose that God, who fills every drop of water with animal life, would create so magnificent and beautiful a world, and leave it to solitude and desolation.

3. There is evidence that beneath the luminous clouds which surround the Sun, there is an inner atmosphere, which seems to be carefully prepared as a veil, to screen the inhabitants of the Sun from too excessive heat.

Is the Sun probably inhabited? What is the first argument in favor of its being inhabited? What the second? What the third?

CHAPTER II.

THE PLANETS—MERCURY—VENUS—THE EARTH.

All those solid celestial bodies resembling the Earth, which revolve around the Sun, are called planets. The planets are divided into two classes. They are the primary and the secondary. The primary planets are those which revolve around the Sun as a centre. There are twelve of them now discovered. They are named Mercury, Venus, the Earth, Mars, Vesta, Astrea, Juno, Ceres, Pallas, Jupiter, Saturn, and Herschel. The primary planets are also divided into superior and inferior. The superior planets are those which are more remote from the Sun than the Earth is. There are nine of them: they are Mars, Vesta, Astrea, Juno, Ceres, Pallas, Jupiter, Saturn and Herschel. The inferior planets are those which are nearer the Sun than the Earth is. There are two of them: they are Venus and Mercury.

What are planets? Into how many classes are planets divided? What are the two classes? What are the primary planets? How many primary planets are there? Name them. Into what classes are the primary planets divided? What are the superior planets? How many superior planets are there? Name them. What are the inferior planets? How many are there? Name them.

The secondary planets are those which revolve around a primary planet as a centre. There are eighteen secondary planets: they are the Earth's moon, the four moons of Jupiter, the seven moons of Saturn, and the six moons of Herschel. Thus there are thirty planets now known as belonging to the solar system. There may be others, also, which have not as yet been discovered.

MERCURY.

The planet Mercury is nearer to the Sun than any other which has yet been discovered. This planet revolves in an orbit distant about thirty-seven millions of miles from the Sun. It is seldom visible, for it is so near the Sun that it is usually hidden in the Sun's rays. Mercury is small compared with the Earth. The Earth is sixteen times larger than Mercury. It is, however, estimated that Mercury could sustain a much larger population than has ever lived, at any one time, upon the Earth. But a very small portion of the Earth has ever been thickly populated. If the planet Mercury were inhabited as densely as is the island of Great Britain, it would support more than eleven times the present population of this globe. Mercury

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What are secondary planets? How many secondary planets are there? Name them. How many planets belong to the Solar System? Is it certain that there are no more? What planet is nearest to the Sun? How far is Mercury from the Sun? Is it often seen? Why is it seldom seen? How much larger is the Earth than Mercury? What is said of the probable population which Mercury could sustain? How large a portion of the Earth has ever been thickly inhabited? How large a population would Mercury support?

performs a revolution around the Sun in about three months, moving with the vast velocity of about one hundred thousand miles an hour. No other planet revolves with so swift a motion. A year on the planet Mercury is of course equal to but three of our months. As Mercury revolves upon its own axis once in about twenty-four hours, a day upon that planet must be of about the same duration as a day with us. Mountains have been seen, by an eminent German astronomer, upon the surface of that planet, and two of them have been measured. The most lofty was found to be about ten miles in height. It is also ascertained that Mercury is surrounded by an exceedingly dense atmosphere. This may perhaps be prepared of such a nature as to screen its inhabitants from the too excessive light and heat of the Sun. It is impossible to ascertain whether Mercury has any attendant moon, for a body so small could not be seen immersed in the Sun's rays. In fact, Mercury is very rarely seen, even with the telescope; it has, however, occasionally been seen with the naked eye.

Notwithstanding the comparative smallness of the planet, it is altogether probable that, in the grandeur

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In what time does Mercury revolve around the Sun? With what speed does Mercury revolve in its orbit? Does any other planet revolve as swiftly? How long is a year on Mercury? In what time does Mercury revolve upon its axis? How long is a day upon Mercury? What is said of the discoveries of an eminent German Astronomer? How high is the loftiest mountain upon Mercury? What is said of the atmosphere of Mercury? What may be the object of so dense an atmosphere? Has Mercury any moon? Why could not a moon of Mercury be seen? Is Mercury often seen with the telescope? Has it ever been seen with the naked eye? What is said to be probable, notwithstanding the smallness of the planet?

of scenery, and in the moral elevation and intellectual dignity of its inhabitants, it holds a far more distinguished rank under the government of God than the world we inhabit.

VENUS.

Venus is the most beautiful of all the planets. This planet revolves in an orbit about seventy millions of miles from the Sun. When in one part of its orbit, it rises just before the Sun, and is then called the morning star; when in the opposite part of its orbit, it sets soon after the Sun, and it is then called the evening star. Venus is of about the same size as the Earth. It revolves upon its axis (thus producing day and night) once in twenty-four hours. Its annual revolution about the Sun is performed in about seven months. Thus, a year upon the planet Venus is equal to but little more than half a year on this globe. The surface of Venus is diversified with mountains and valleys. Many of these mountains are far more lofty than any which are beheld on the Earth. One mountain is visible which is estimated to be more than twenty miles in height. The highest on the Earth are not more than five miles in height; consequently,

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Which is the most beautiful of the planets? What is the distance of Venus from the Sun? When is Venus called the morning star? When is it called the evening star? What is the size of Venus? In what time does it revolve upon its axis? In what time does it revolve about the Sun? How long is a year upon Venus? What is said of the surface of Venus? What is said of the height of many of these mountains? How high is one estimated to be? How high are the highest on Earth?

the scenery upon Venus must be far more sublime than any which we witness. Clouds creep up the sides of these majestic mountains, and float in the atmosphere with which the planet is enveloped. Apparently, there are no very large bodies of water, like our oceans, upon the planet Venus. The clouds, however, floating in the atmosphere, indicate that the planet is supplied with lakes and rivers. To an inhabitant of Venus, the Sun appears twice as large as it does to us, and the planet Mercury is her morning and evening star. When the Earth and Venus are in a particular position, Venus may be seen, appearing like a black ball, passing over the surface of the Sun. This phenomenon is called a transit of Venus. These transits are of very rare occurrence. It is uncertain whether Venus has any satellite, or moon. If Venus have a satellite, it must, in consequence of its distance, and its proximity to the Sun, be very difficult to be seen. Many astronomers, however, think that, in certain favorable positions, they have discovered a moon revolving around Venus, of about the same size as our moon. It is estimated that Venus would sustain a population more than sixty-seven times the present population of the Earth ; consequently, it may be in rank a world of far greater importance than our own.

What is said of the scenery upon Venus ? What is said of clouds on the planet Venus ? Are there large bodies of water on Venus ? What do the clouds indicate ? How large does the Sun appear to an inhabitant of Venus ? What is the morning and evening star to an inhabitant of Venus ? What is a transit of Venus ? Has Venus any moon ? Why cannot her moon, if she have any, be easily seen ? What do many astronomers think ? What population would Venus sustain ?

THE EARTH.

The third body in the solar system is the Earth. The form of the Earth is that of a globe, a little flattened at the two ends, like an orange. Such a figure is called an oblate spheroid. The diameter of the globe, from east to west, is about thirty-four miles longer than from north to south. The Earth is eight thousand miles in diameter, and twenty-five thousand miles in circumference. The atmosphere which surrounds the globe, is about forty miles in thickness The Earth revolves in an orbit, at the distance of nine ty-five millions of miles from the Sun; and rushing along its pathway, with the velocity of a thousand miles a minute, it performs its annual revolution in three hundred and sixty-five days, six hours, nine minutes and twelve seconds. It is, indeed, a sublime idea, that the world in which we dwell is thus careering onward, through the depth of space, with such fearful velocity. We pass through sixty thousand miles of space every hour.

Though the Earth is not a perfect globe, yet it is so nearly so, that if a perfect model of the Earth were made, the eye could not detect that it was not perfect-

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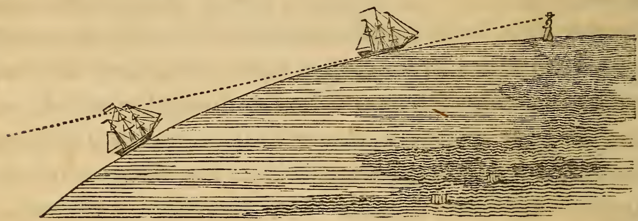
What is the third body in the Solar System? What is the form of the Earth? What is such a figure called? What difference is there in the diameter of the Earth? Which diameter is the longest? What is the length of the Earth's diameter? What is its circumference? What is the thickness of the Earth's atmosphere? What is the distance of the Earth from the Sun? With what velocity does it revolve? In what time does it perform its annual revolution? What space do we pass through each hour? How nearly a perfect globe is the Earth?

ly round. There are various and conclusive proofs, that the Earth is of a globular form.

1. It has been sailed around.

2. A ship receding from the shore exhibits the tops of the masts, as is illustrated in the diagram, when the body of the ship is below the horizon.



3. The shadow which the Earth casts upon the Moon in an eclipse, is precisely that which one globe would project upon another globe.

Some may suppose that the Earth cannot be considered as globular, in consequence of the lofty ridges of mountains upon its surface. But the inequality caused by the mountains, is not at all incompatible with the idea of its spherical form. The highest mountains on the Earth are not more than five miles in height. The diameter of the Earth is eight thousand miles; consequently, the proportion of the highest pinnacle of the loftiest mountain to the diameter of the globe, is but as five to eight thousand, or one to sixteen hun-

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What is the first proof that the Earth is round? What the second? What the third? Why do some think that the Earth cannot be considered globular? What is said of this inequality? How high are the highest mountains? What is the proportion of these mountains to the diameter of the globe?

dred. The surface of the Earth, in consequence of its mountainous inequalities, has sometimes been compared with the roughness on the rind of an orange. But this illustration assigns altogether too great a comparative elevation to the height of the mountains. If you take a globe sixteen inches in diameter, and paste upon it a strip of the thinnest paper, the thickness of that paper would represent the loftiest range of mountains on the Earth. Such is the comparative height of the inaccessible pinnacles of Mt. Blanc. When we think of men, thronging such valleys, and toiling for weary days in the ascent of such acclivities, well may we inquire, in the language of the inspired penman, "What is man, that thou art mindful of him, and the son of man, that thou deignest to visit him?"

It is also supposed that the greatest depth of the ocean does not exceed the height of the mountains; consequently, on a sixteen-inch globe, the ocean would be represented by the thinnest film of water laid upon it with a brush. The slightest scratch of a pin would represent the Mississippi and the Amazon. These illustrations show that, notwithstanding our towering mountains and deep valleys, the Earth may be regarded as a true globe.

As the orbit of the Earth is not exactly circular, the Earth is at certain seasons of the year about three

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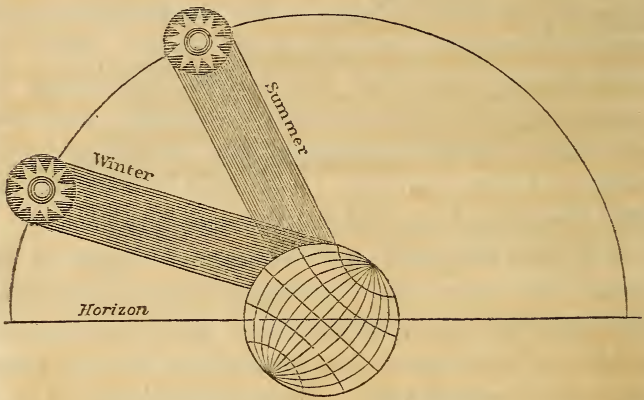
To what has this inequality sometimes been compared? Why is not this a good comparison? What would be a correct representation of the loftiest mountains? What is the greatest depth of the ocean supposed to be? What would correctly represent the depths of the ocean? What would represent the Mississippi and the Amazon? What do these illustrations show? Why is the Earth at one time nearer the Sun than at others?

millions of miles nearer the Sun than at other seasons. The Earth is nearest the Sun about the first day of January; but as the rays of the Sun then fall obliquely upon the Earth, the cold is severe. The Earth is farthest from the Sun about the first of July. But as the rays of the Sun then fall nearly perpendicularly upon us, the heat is oppressive. The diagram illustrates this principle. About the 21st day of March



and the 23d of September, the Sun crosses the equator, and the days and nights are then equal in length in all places. These periods are called the equinoxes, from two Latin words, signifying equal nights. When the Sun passes the equator in March, it is called the vernal equinox. When it passes the

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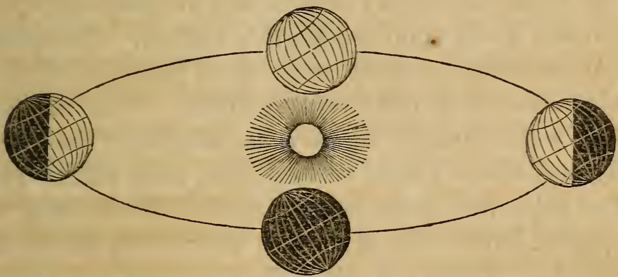
How much nearer is it at one season than at another? When is the Earth nearest the Sun? Why is it then so cold? When is the Earth farthest from the Sun? Why is it then so warm? When does the Sun cross the equator? What is the comparative length of the days and nights then? What are those periods called when the days and nights are equal? What is the vernal equinox?

equator in September, it is called the autumnal equinox. The time between the vernal and autumnal equinox is about eight days longer than the time between the autumnal and the vernal equinox.

The shortest day and the longest night north of the equator are on the 21st of December. This time is called the winter solstice. It is so called from two Latin words, signifying that the Sun stands or stops. At that time, the Sun apparently ceases going any farther south, and returns again towards the north. Crossing the equator, it arrives at its extreme northern limits on the 21st of June. At this time we have the longest day and the shortest night, and this is called the summer solstice.



Nearly three-quarters of the surface of the Earth is covered with water. The present population of the

What is the autumnal equinox? Between which of the equinoxes is there the longest time? How much the longest? When is the shortest day? What is this period called? From what is this name derived? What change is there then in the apparent movement of the Sun? When does the Sun arrive at its extreme northern limit? What is the comparative length of the day at that time? What is that period called? What portion of the Earth's surface is covered with water? What is the present population of the globe?

globe is estimated to be about one thousand millions. Were all the habitable portions of the globe peopled as densely as England, the Earth would sustain nearly twenty times its present population. But war, the greatest scourge which has ever afflicted humanity, has thus far so thinned out the number of the human family, that but about one-seventeenth of the habitable globe is yet peopled. If it were not for past wars and the vices of mankind, every habitable portion of the globe would be smiling with cultivated fields and peaceful villages. And the spirit of war, which even now is cherished, in sustaining expensive armies and navies, is one of the most serious obstacles which now exist in the way of human improvement.

It is often necessary to ascertain the particular position of a place upon the Earth's surface. To do this, it is necessary to settle some fixed points or lines to which we may refer various places. One of these lines is the equator, which is an imaginary line, passing around the centre of the Earth, from east to west. The poles are those points, equally distant from the equator, where the axis of its diurnal revolution terminates. These are called the north and south poles. The hemispheres, or half-spheres, into which the equator divides the globe, are called the northern and southern hemispheres. The distance of any place

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What population could this Earth sustain? What has been the effect of war? What would have been now the case if wars and other vices had not prevailed? What is the influence of the present war-spirit? What is first necessary to ascertain the position of a place upon the Earth's surface? What is the equator? What are the poles? What are the poles called? What are the two hemispheres into which the equator divides the Earth called? What is Latitude?

from the equator is called its latitude, and latitude is consequently reckoned in the direction of north and south, and a place is said to be in northern and southern latitude as the place is in the northern or southern hemisphere. But while the latitude will determine how far a place is north or south of the equator, it does not indicate its position east or west of any given place, for the line of latitude of course encircles the globe. The distance of a place east or west of any assumed point is called longitude. To ascertain the longitude of a place, the earth is supposed to be encircled by a line, dividing it into two equal parts, passing through some place which is assumed as the point from which to measure the longitude. Washington has sometimes been assumed. Philadelphia has also been selected as the point from which longitude is reckoned. In England, the Royal Observatory is erected at Greenwich, a short distance from London; consequently, in all English works, longitude is reckoned from the meridian of Greenwich. These, then, are the standards of reference from which to decide the position of any place on the surface of the globe. When it is said that the city of New York is situated in about 41 degrees north latitude, and about 75 degrees west longitude, it is meant that the city is 41 degrees north of the equator, and 75 degrees west

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When is a place said to be in North Latitude? When in South Latitude? What is Longitude? To ascertain the Longitude of a place, what is supposed? What places in America have been assumed as the points from which Longitude is reckoned? Where is the Royal Observatory in England? From what place is Longitude reckoned in English works? What is meant by the assertion that the City of New York is in 41° North Lat. and 75° West Long.?

of the meridianal line which passes over the Observatory of Greenwich.

The process by which the latitude of any place, either on the land or sea, is discovered, is very simple. A circle is divided into three hundred and sixty degrees. From the equator to either pole is a quarter of a circle, or ninety degrees. By a very simple instrument, the point in the sky directly overhead, which is called the zenith, is ascertained. By observation, the distance of that point from the north pole is determined. Suppose this distance to be sixty degrees, that number subtracted from ninety degrees, which is a quarter of a circle, will designate the precise distance of the place from the equator. An instrument called Hadley's Sextant is generally used at sea for making such observations.

There is another mode of ascertaining the latitude, which is, however, essentially the same in principle. The distance of the Sun from the equator is called its declination. The declination of the Sun is known, and registered in tables for every day in the year. By ascertaining, by observation, the distance of the Sun from the zenith, and adding that distance to the Sun's declination, the latitude of the place is determined.

To find the longitude of a place by observation, is much more difficult, as there are no visible fixed points

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Into how many degrees is a circle divided? How many degrees is it from the equator to either pole? What is the point in the sky directly overhead called? Describe the first mode of ascertaining the Latitude. What instrument is generally used? What is the distance of the Sun from the equator called? Describe the second mode of ascertaining the Latitude. Why is it more difficult to ascertain the Longitude?

from which to calculate. The usual mode is the following. The Sun appears to pass around the globe in about twenty-four hours; and as the circumference of the globe, and of every circle, is divided into three hundred and sixty degrees, the sun passes over fifteen degrees in one hour. Consequently, when it is twelve o'clock in Greenwich, fifteen degrees west of Greenwich it will be eleven o'clock, and thirty degrees west it will be ten o'clock, and forty-five degrees west it will be nine o'clock. By this simple principle, longitude is usually calculated. The mariner takes with him a watch or time-keeper of the most perfect construction, called a chronometer. This is set according to the time at Greenwich; and, consequently, will inform him, wherever he may be, what o'clock it is at the Royal Observatory. At noon he takes an observation, when the sun is in the meridian, and thus ascertains that it is twelve o'clock. He looks at his chronometer, and finds that at that moment it is one o'clock at Greenwich. He thus knows that it will require the Sun just one hour to move, in its apparent orbit, from Greenwich to where he is; and as the Sun's apparent motion is fifteen degrees an hour, he knows that he is in the longitude of fifteen degrees west of Greenwich. Such are the general principles on which latitude and longitude are calculated. It is not necessary to explain here the corrections necessary in the practical workings of these methods.

Over how many degrees does the Sun appear to pass in one hour? When it is 12 o'clock in Greenwich, what time will it be 15° West of Greenwich? What time 30° West? What time 45° West? What is a chronometer? Describe the first mode of ascertaining the Longitude.

There is another mode of ascertaining the longitude of a place, by what is called a lunar observation. It has been thus eloquently described by Dr. Lardner: "The astronomer supplies the mariner with a chronometer of unerring precision; a chronometer which can never go down nor fall into disrepair; a chronometer which is exempt from the accidents of the deep; which is undisturbed by the agitation of the vessel; which will at all times be present and available to him, wherever he may wander over the trackless and unexplored regions of the ocean. Such a chronometer has been found, made by an artist who cannot err, and into whose works imperfection can never enter. Such a chronometer is supplied by the firmament itself. The unwearied labors of modern astronomers have converted the face of the heavens into a clock, and have taught the mariner to read its complicated but infallible indications. We may regard, for this purpose, the firmament as a dial-plate of a chronometer, on an immense scale. The constellations and the fixed stars upon it, which for countless ages are subject to no change in position, serve as the hour and minute marks. The Sun, the Moon, the planets and the satellites, which move continually over the surface of this splendid piece of mechanism, play the parts of the hands of the clock. The position of these bodies from day to day, and from hour to hour, and every change of their position, are accurately foreknown, and exactly registered in a book published some

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What is the second mode of ascertaining the Longitude called? Give the substance of Dr. Lardner's description. Describe the second mode of ascertaining the Longitude.

two or three years in advance, called the 'Nautical Almanac,' and circulated for the benefit of mariners. In this work, the navigator is told what the hour is, or will be, at Greenwich, for every variety of position which the Sun, Moon and planets shall have, from time to time, upon the heavens. But of all the objects in the heavens, that which is best suited for this species of observation is the Moon. And hence, this method of determining the longitude at sea has been distinguished by the appellation of the *lunar method*." The mariner, with the sextant, observes the distance of the Moon from the Sun. The Nautical Almanac informs him what o'clock it is at Greenwich when the Moon is in that position; and knowing the hour where he is, he easily calculates his distance from Greenwich.

CHAPTER III.

THE MOON—MARS.

Telescopic View of the Moon.

A Moon, or satellite, is a planetary body which revolves around a primary planet as its centre. It is sometimes called a secondary planet. In an orbit, distant about two hundred and forty thousand miles from the Earth, our Moon revolves. Though the Moon is the nearest to us of all the celestial bodies, it would require nearly a year and a half to journey to it, travelling day and night, at the rate of twenty miles an hour.

The Moon is about two thousand miles in diameter. It is in bulk equal to but about one fiftieth part of the Earth; and still, if it were inhabited as densely as the island of Great Britain now is, it would sustain

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What is a Moon or satellite? What is it sometimes called? At what distance from its primary does the Earth's Moon revolve? What celestial body is nearest to the Earth? How long would it take to reach the Moon, travelling at the rate of twenty miles an hour? How long is the diameter of the Moon? What is its size compared with the Earth? How large a population could it sustain?

five times as many inhabitants as dwell at the present time upon the Earth. The Moon revolves upon its axis once in about twenty-eight days. Consequently a day and night upon the Moon is equal in length to a month on the Earth. The Moon performs a revolution upon its axis in the same time in which it revolves around the Earth. It therefore always turns the same face to us. We never see but one and the same hemisphere of the Moon. The inhabitants who live upon the hemisphere turned from us, never see the Earth. As the Moon accompanies our Earth in its circuit around the Sun, it performs its revolution around that luminary in the same period of time with the Earth. While, therefore, a year on the Moon is as long as a year with us, it takes but twelve lunar days, each a month in length, to compose a lunar year.

The surface of the Moon is diversified with mountains and valleys. The mountains and caverns which exist upon the Moon are thrown together in the most sublime disorder. The height of great numbers of these mountains has been accurately measured. Many of them are ranges several hundred miles in extent, and rising from two to five miles in height.

There are large circular cavities or caverns existing on the face of the Moon, constituting a feature in lunar

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In what time does the Moon revolve upon its axis? What is the length of a day and night upon the Moon? Why does the Moon always turn the same face to us? In what time does the Moon perform its circuit around the Sun? How long is a year on the Moon? How long is a day? How many lunar days are there in a year? What is said of the surface of the Moon? What is the size of the mountain ranges?

scenery, totally dissimilar from anything which is seen on Earth. These cavities are nearly circular in form, and their dimensions vary from three miles to fifty miles in diameter at the top, and some of them are three and a half miles in perpendicular depth. Many Astronomers have declared that with powerful telescopes, they have witnessed volcanoes on the Moon, throwing out volumes of flame and smoke. Others, who have observed the same luminous appearances, have considered them either as lights of a phosphoric nature, or some artificial illumination of the inhabitants, rather than the eruption of volcanic fires.

It has often been asserted that there is no water upon the Moon. There is, however, not sufficient evidence for so sweeping an assertion. It is admitted, however, by all Astronomers, that upon that half of the Moon which is visible to us, there are no large oceans or seas. There may, however, be rivers and small lakes, which the telescope does not bring to view. And there may be large oceans rolling upon that hemisphere which is ever secluded from earthly eyes.

The question whether the Moon has an atmosphere, has also for a long time been disputed. Many Astronomers are now of the opinion, that the Moon has an atmosphere. No clouds are, however, ever detected

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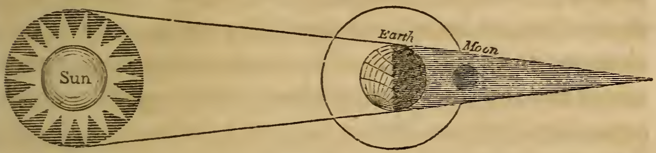
What peculiar scene is witnessed in lunar scenery? What is the form of the lunar cavities? What their extent? What is said respecting volcanoes in the Moon? What assertion has been made respecting water in the Moon? Is it certain that there is no water there? What is admitted by all Astronomers? What may exist upon the Moon though unseen by us? What is said respecting the Moon's atmosphere? What is the present general opinion? What is said respecting clouds in the Moon's atmosphere?

in that atmosphere, to darken its serene sky. The Moon is eclipsed when the Earth, passing between the Sun and the Moon, casts its shadow upon that satellite, as is exhibited in the accompanying cut. In the an-



nular eclipse of 1836, a distinguished observer says, "just before the rims of the two bodies met, the light of the Sun shot through the Moon's atmosphere mollified into lovely twilight." Lardner says, "it may be considered as demonstrated that the Moon has no atmosphere." Schrœter, a very eminent Astronomer, who has passed years in examining the Moon with the most powerful glasses, says, that he has ascertained with absolute certainty that the Moon has an atmosphere.

There has long existed an almost universal impression, that the changes of the weather are influenced by the changes of the Moon. If the weather be fair or foul, it is supposed that at the period of new or full Moon, or at the epochs of the quarters, there will be a change. This almost universal impression is, however, totally without foundation. There are no principles of science upon which to base such a theory.

When is the Moon eclipsed? What is Lardner's opinion? What is Schrœter's? What impression respecting the influence of the Moon has long existed? At what period is it supposed that a change of weather will take place? Does the Moon have any perceptible influence on the weather?

The question of fact has also been settled by long and careful observation. Registers of the weather have been kept, in Europe, for long periods of time; every change being noticed and registered, from day to day, and for years, with the utmost minuteness. And these changes have been carefully compared with the changes of the Moon. The result of this experiment, again and again repeated, has proved with absolute certainty, that the lunar phases have no perceptible influence whatever upon the weather.

It is also a popular prejudice, that certain kinds of timber should be cut only during the decline of the Moon, or it will soon decay; and also that trees should be planted, pruned, &c., only during the increase of the Moon. Accurate and long continued observation has proved that these notions have no support from facts.

The deleterious influence of the Moon upon the insane has been considered so decisive, that he who is disordered in his mind is still called a *lunatic*, or one *moon-struck*. This opinion is also unsustained by any satisfactory evidence. Dr. Olbers, a distinguished physician and Astronomer, asserts that "in the course of a long medical practice, he was never able to discover the slightest trace of any connection between the phenomena of disease and the phases of the Moon.

It is the general opinion of Astronomers that the Moon is inhabited. Though we cannot hope by any increase

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How is this proved? What is the popular impression respecting the influence of the Moon upon timber? Why is an insane man called a lunatic? What is the testimony of Dr. Olbers? Is the Moon supposed to be inhabited?

of telescopic power, within the limits of probability, to see inhabitants on the Moon, it is not unreasonable to suppose that their works may be seen. In order to discern an object on the Moon as small as a man, a telescope must be used which has a magnifying power of one hundred thousand times. But such a telescope has never yet been constructed. Herschel's large telescope, the largest ever constructed, possessed a magnifying power of six thousand. This noble instrument was about forty feet in length, and five feet in diameter. A telescope whose magnifying power is twelve hundred, will enable us to discern objects on the Moon which are three hundred feet in diameter. As there are many glasses of this magnifying power, it is very possible that cities and other large works may be discovered.

Professor Gruithausen, of Munich, declares that he has discovered, by his large telescope, cities, fortifications, roads and other artificial works, erected by the inhabitants of the Moon. He has even proposed the plan of opening a telegraphic correspondence with the inhabitants of that world. He suggests the erection, upon the plains of Siberia, of a vast geometrical figure. He thinks that the inhabitants of the Moon, seeing this figure through their telescopes, might regard it as a signal, and thus be induced to erect a similar one in reply.

What must be the magnifying power of a telescope to discern a man upon the Moon? What was the magnifying power of Herschel's large telescope? What was the length of this instrument? How small an object can be seen on the Moon, with a telescope which will magnify twelve hundred times? What does Professor Gruithausen declare? What plan has he proposed?

When we reflect upon the magnitude of the Moon, and the vast population it is capable of sustaining, it does not seem probable that the Creator would erect such a world, and abandon it to solitude.

The tides of the ocean are caused by the attraction of the Moon. As the Moon revolves around the Earth, it attracts the water, and it follows the path of the Moon in a vast wave, several feet in height, flowing into all the bays and rivers and inlets. As the Moon comes to the meridian about half an hour later each day, the tide is consequently each day later. The highest tide is not directly under the Moon, but follows its path an hour or two in the rear. But in addition to the tide which follows the Moon there is another tide upon the side of the globe directly opposite. It is difficult to explain the cause of this, so as to make it perfectly familiar to the reader who is not skilled in scientific studies. It cannot, however, perhaps, be explained in language more perspicuous than that in which it is described in the Encyclopedia Americana. "If the Earth rested immovably upon a fixed support there would be a tide only on the side towards the Moon. But the great body of the Earth is just as free to move as a single particle of the ocean, and if suffered to yield to the Moon's attraction, would be carried just as fast. Hence, for the same reason that a particle of

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Why should we suppose that the Moon is inhabited? By what are the tides caused? How does the Moon create a tide? How much later is the tide each day? Why is it thus later? When is the highest tide? What other tide is there in addition to the one which follows the Moon? Is this second tide easily explained? From what book is an explanation taken? If the Earth were immovable, how many tides would there be? What is said respecting the freedom of the Earth to move?

water, on the side of the Earth towards the Moon, is drawn away from the centre, or has its downward tendency diminished, so the solid Earth itself is drawn away from the mass of waters, on the side of the Earth farthest from the Moon. It is the difference of attraction, in both cases, between the surface and the centre which causes the lightness of the waters and the consequent elevation." The tides are highest when the Sun and Moon attract in concert. These are called *spring tides.* When the Sun and Moon are opposite, and counteract each other, the tides are lowest. These are called *neap tides.*

MARS.

The next planet in the Solar system, as we leave the Earth and its accompanying Moon, is Mars. This planet revolves in an orbit, one hundred and forty-five millions of miles from the Sun. When Mars is at its greatest distance from the Earth, it is separated from us by a space of two hundred and forty millions of miles. When it is nearest the Earth, it is but fifty millions of miles from us. But even when nearest the Earth, it would require, to pass from the Earth to Mars, travelling at the rate of twenty miles an hour, about two hundred and eighty-five years. When at its greatest distance it would require more than a thou-

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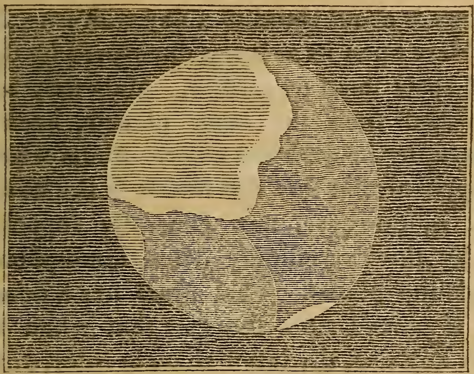
What is drawn away from the mass of waters ? What causes the rising of the waters in both tides ? What planet is next beyond the Earth in the Solar system ? What is the distance of Mars from the Sun ? What is Mars' greatest distance from the Earth ? What is its nearest distance from the Earth ? How long would it take to reach Mars when nearest to us, travelling at the rate of twenty miles an hour ? How long would it take when Mars is farthest from us ?

sand years. When the Sun and Mars are on the same side of the Earth, Mars is said to be in conjunction. When the Earth is between Mars and the Sun, Mars is in opposition. When Mars is in opposition, Mars and the Earth are nearest together. Mars then appears twenty-five times larger than when in conjunction. The following diagram will make this perfectly intelligible.

Mars performs its annual revolution around the Sun in six hundred and eighty days. Thus a year on the planet Mars is equal to about two years on the Earth.

When is Mars said to be in conjunction? When in opposition? When are Mars and the Earth nearest together? How much larger does Mars appear when in opposition than when in conjunction? In what time does Mars perform its revolution around the Sun? How long is a year on Mars?

It revolves in its annual orbit with a rapidity more than a hundred times greater than a cannon ball at its greatest velocity. Sir John Herschel says, that land and water evidently exist on the planet Mars, and that



about one-third of its surface is water. It is also evident that Mars is surrounded with a very dense atmosphere, in which clouds are occasionally seen floating. A variety of seasons must also exist upon this planet, somewhat similar to ours. In the winter, the northern regions of Mars are whitened with snow, which disappears with the return of the summer's sun. This planet is about four thousand miles in diameter, which is but one-half the diameter of the Earth. Still it is sufficiently large to sustain twelve times the present

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With what velocity does this planet revolve in its orbit? What does Sir John Herschel say respecting Mars? What is said of the atmosphere of Mars? What is said of the seasons on Mars? What appearance of snow is perceived on this planet? What is the diameter of Mars? How does that compare with the diameter of the Earth? What population would Mars sustain?

population of the Earth. No moon has yet been discovered revolving about Mars. But it is by no means improbable that Mars has a moon, which is undistinguishable by any of our telescopes. Mars revolves upon its axis in about twenty-four hours, so that a day upon Mars is about equal to a day with us. The rotation of Mars upon its axis was discovered by the movement of spots upon its surface. Mars may be readily distinguished from the other planets, even by the naked eye, by its dark red color. Some Astronomers have supposed that this was owing to the nature of its soil. It is, however, now generally supposed to be caused by the exceedingly dense atmosphere which surrounds the planet. That Mars has a dense atmosphere, is proved from the fact that when Mars approaches any star, the latter changes color, grows dim, and often disappears, even when at quite a distance from the body of the planet. If Mars has no moon, it is supposed that a compensation for the absence of a satellite, may be furnished by the peculiar depth and density of its atmosphere. The four planets, Mercury, Venus, the Earth and Mars, are frequently called *terrestrial planets*. They are so called because they so much resemble each other.

Has Mars a moon? In what time does Mars revolve upon its axis? How long is a day upon Mars? How was the rotation of Mars discovered? How may Mars be distinguished from the other planets? To what have some Astronomers supposed this color to be owing? By what is it now supposed to be caused? How is it proved that Mars has a dense atmosphere? What compensation may Mars have for a moon? What four planets are called *terrestrial planets?* Why are they so called?

1. They have a general resemblance in point of magnitude.

2. They are similar in their geographical character.

3. They have nearly the same length of days and nights.

4. They are diversified with climates and supplied with atmospheres and clouds.

What is their first point of resemblance? What their second? What their third? What their fourth?

CHAPTER IV.

VESTA—ASTREA—JUNO—CERES—PALLAS—JUPITER.

About half way between Mars and Jupiter, five very small planets have been discovered. They are generally called the Asteroids—and have been named Vesta, Astrea, Juno, Ceres, Pallas. The observation of the immense distance between Mars and Jupiter, led Astronomers to imagine that there must be some intervening planet. For while the distance between the orbits of the Earth and Mars is but about twenty-five millions of miles, the distance between the orbits of Mars and Jupiter is over three hundred millions. In searching for an intermediate planet, instead of finding one large one, these four small ones were found. And various considerations have led to the supposition that these four planets are the fragments of some majestic world, which, by some terrible convulsion, has been blown in sunder. This supposition is rendered plausible, 1st, by the fact that the Asteroids are not round,

What planets are found between Mars and Jupiter ? What are they generally called ? What led to the discovery of these planets ? What is the distance between the orbits of the Earth and Mars ? What is the distance between the orbits of Mars and Jupiter ? What are the Asteroids supposed to be ? What is the first fact which supports this supposition ?

like the other planets, but angular like irregular fragments.

2dly. The intersection of their orbits is precisely the same that it would be, if they had been driven apart by an explosion.

VESTA.

Vesta is the first of the Asteroids. It is but two hundred and seventy miles in diameter, and presents a surface about equal to Great Britain, France and Ireland. This comparatively little globe might sustain a population of about sixty millions. Vesta is seldom, if ever, visible to the naked eye. Its revolution around the Sun is performed in about three years and a half. Though, in all probability, it revolves upon its own axis, the planet is so small that its diurnal revolution cannot be detected. Vesta was not discovered until the year 1807.

ASTREA.

A new planet has recently been discovered between the orbits of Vesta and Juno, which has received the name of Astrea. It was first recognized as a planet on the 8th of December, 1845, by Professor Hencke of Dresden, situated then between the stars of the ninth magnitude in the constellation of Taurus. On

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What is the second fact which supports it? What is the first of the Asteroids? What is the diameter of Vesta? How large is its surface? What population would Vesta sustain? In what time does Vesta revolve around the Sun? Does Vesta revolve upon its own axis? When was Vesta discovered? Where has a new planet recently been discovered? What name has it received? When was it discovered? By whom? In what constellation was it then seen?

the 14th of the same month it was seen by Professor Encke, and by him named by the request of the first discoverer. The European observers make its distance from the Sun two hundred and fifty millions of miles. It probably belongs to the group to which Sir William Herschel gave the name of Asteroids. And yet it is exceedingly difficult to imagine how it could have escaped the scrutiny of the twenty-six observers who, in the year 1800, united for the purpose of examining all the telescopic stars of the Zodiac, to detect that planet which they supposed must occupy the gap between Mars and Jupiter. This circumstance might lead to the conclusion that it is a new planet, or a changeable one.

JUNO.

The third of the Asteroids is Juno. This is considerably larger than Vesta, being estimated by some Astronomers to be about fourteen hundred miles in diameter, or nearly the size of our Moon. It is capable of sustaining twice the present population of the globe. This planet revolves around the Sun in about four years, and has a very dense atmosphere.

Who next saw it? When did he see it? Who named it? What is its distance from the Sun? To what group does it probably belong? Who named that group? What difficulty is suggested? To what opinion may this circumstance lead? What is the third of the Asteroids? How large is Juno? What population would Juno sustain? In what time does Juno revolve around the Sun? Has Juno an atmosphere?

CERES.

The fourth Asteroid is Ceres. It is of about the same size with Juno, being sixteen hundred miles in diameter. In extent of surface, it is equal to about one-sixth of the habitable globe. If inhabited as densely as England, it would sustain three times the present population of the earth. Ceres is never seen by the naked eye. Its atmosphere is about seven hundred miles in thickness. Ceres revolves around the Sun in four years. The period of its diurnal revolution is not known.

PALLAS.

The fifth of the Asteroids is Pallas. Its diameter has not yet been ascertained. It is however supposed to be of about the size of the Earth's moon. Pallas revolves around the Sun in four years. The time in which it performs its diurnal revolution is not ascertained. Indeed, the Asteroids are so small that the size of none of them is with *certainty* determined.

The assumption that the Asteroids are the fragments of an exploded planet helps to explain the mysterious

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What is the fourth Asteroid? What is its size? What is its extent of surface? What population can Ceres sustain? Can Ceres be seen by the naked eye? What is the thickness of its atmosphere? In what time does Ceres revolve around the Sun? What is the period of its diurnal revolution? What is the fifth of the Asteroids? What is the diameter of Pallas? What is its supposed size? In what time does Pallas revolve around the Sun? What is the period of its diurnal revolution? What is explained by the assumption that the Asteroids are fragments of an exploded planet?

phenomenon of meteoric stones. There are hundreds of well-authenticated instances of showers of stones, some of them of very large size, falling from the sky. These stones do not resemble any substances which exist upon the Earth, while they all, in whatever part of the world they may fall, are similar in character. Five theories have been adopted by philosophers to explain the phenomenon of falling stones.

1. The Atmospheric Hypothesis. This supposes that these stones are formed in the air, in a manner somewhat analogous to hail-stones. But while we can easily imagine that vapor may be congealed into ice, we cannot imagine how pure air can be consolidated into iron and stone.

2. The Volcanic Hypothesis. This supposes that these meteoric stones are thrown from some vast unknown volcano on the surface of the Earth. But now the Earth's surface has been sufficiently explored to prove that there is no volcano capable of throwing stones to the distances where these meteoric stones fall.

3. The Lunar Hypothesis. According to the lunar hypothesis, these stones are thrown from volcanic mountains in the Moon, called lunar volcanoes. It is however hardly supposable that there have ever been volcanoes in the Moon of such power as to throw large masses of stone for several thousands of miles, until they had passed the region of the Moon's attraction; and there is no evidence that there are any volcanoes

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How many theories have been proposed to explain the phenomenon of meteoric stones? What is the first hypothesis called? What is this hypothesis? What is the second? Explain the volcanic hypothesis. What is the third hypothesis? Explain it.

in the Moon, now in active operation. This theory is now generally abandoned.

4. The Nebular Hypothesis. According to the nebular hypothesis, meteoric stones proceed from chaotic matter, which is diffused in various positions throughout the universe, and which is supposed to constitute the peculiar appearance in the heavens called nebular. There are, however, no reasons to be advanced in favor of this supposition.

5. The Planetary Hypothesis. The supposition now generally advocated is, that these stones are the smaller fragments of that planet whose explosion, it is imagined, formed the Asteroids. These fragments, circling through the depths of space, are occasionally brought within the influence of the Earth's attraction. They then fall to the surface. Extravagant as this supposition may seem to be, it is the most plausible of any, and is the one now generally adopted. And still it is not easy to account for the luminous appearance which usually accompanies these falling stones, and their evident exposure to intense heat.

There are very many well-authenticated instances of the fall of these meteoric stones. The following brief accounts will give a general idea of this phenomenon.

On the 26th of April, 1803, at L'Aigle in Normandy, at noon of a bright and serene day, a noise was heard resembling thunder. A fiery ball was seen rushing through the atmosphere with great rapidity. It exploded with a report which was heard for nearly a

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What is the fourth hypothesis? Explain it. What is the fifth hypothesis? Explain the planetary hypothesis.

hundred miles in every direction, and immediately a shower of stones, with a hissing noise, was precipitated with immense velocity to the earth. The largest of the stones weighed seventeen pounds. One fell at the feet of a young lady standing in a yard, and rebounded more than a foot from the pavement. A stone grazed the arm of a workman, and as he attempted to pick it up, it was so hot that he was compelled instantly to drop it. The government of France deputed a distinguished philosopher to repair to the spot and collect all the authentic facts in relation to this phenomenon.

Several stones have fallen weighing between two and three hundred pounds. On the 24th of July, 1790, one fell in the vicinity of Bordeaux and crushed the hut of a herdsman, killing its occupant.

These stones are all of the same general character, and yet are quite different from any substances which are found existing upon the Earth.

JUPITER.

The planet which revolves next beyond the Asteroids is Jupiter. This is the largest orb, with the exception of the Sun, in the planetary system. In performing its vast circuit around the Sun, it occupies nearly twelve years, moving at the rate of twenty-eight thousand miles an hour; so that a year upon that planet is equal to

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Describe the fall of meteoric stones in Normandy. How heavy have any meteoric stones been? What planet comes next to the Asteroids? What is the largest planet in the Solar System? In what time does Jupiter revolve around the Sun? With what speed does it revolve? How long is a year upon that planet?

twelve of ours. Its revolution upon its axis is accomplished in about ten hours. A day and night upon that planet are therefore equal to but ten hours; and it has more than ten thousand days in its year. This planet is about five hundred millions of miles from the Sun, and is never nearer to the Earth than four hundred millions of miles. To pass from this Earth to Jupiter, when we are nearest that planet, moving at the rate of twenty miles an hour, would occupy two thousand three hundred years. This majestic orb is eighty-nine thousand miles in diameter. It is equal in bulk to fifteen hundred such worlds as we inhabit, and would support a population of more than fifty times as many as have existed upon the Earth during the whole period since the creation. On the planet Jupiter there is very little difference in the length of the days and nights. We have our long summer days and short winter days; but with the inhabitants of Jupiter there is no such variety. Neither are there any changes from summer's burning heat to winter's piercing cold. The temperature in any one place is always essentially the same. This results from the fact, that the axis upon which the planet revolves is almost perpendicular to the plane of its orbit. Some

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How long is a day and night upon Jupiter? How many days has it in a year? What is the distance of this planet from the Sun? What is its nearest distance? How long would it take to pass from the Earth to Jupiter, moving at the rate of twenty miles an hour? What is the diameter of Jupiter? How much larger is it than the Earth? What population would it support? What is said of the difference in the length of the days and nights on this planet? What is said of the changes from summer to winter? Why is the temperature always essentially the same in one place?

astronomers have supposed that everlasting winter prevails about the poles of this planet; but it is altogether probable that some arrangements are adopted to reflect light and heat to different portions of its surface, that all its inhabitants may enjoy the benefits of a congenial clime. The fact that the planet, though at so immense a distance from the Sun, shines with such peculiar brilliancy, is evidence that the atmosphere of this majestic world is arranged to reflect the light of the Sun in a peculiar manner. Whether Jupiter has an atmosphere resembling in its properties that which surrounds this Earth, has not yet been ascertained. Lardner thinks that there is evidence of atmospheric currents in Jupiter, similar to those which prevail on the Earth, blowing constantly from east to west in some latitudes, and from west to east in others.

The surface of Jupiter, when seen through a good telescope, always presents a peculiar aspect of floating clouds in the atmosphere, or belts on the disc of the planet. It is now generally supposed that these dark belts are the body of the planet seen through openings in the brightly-illuminated clouds, which always float above its surface. These stripes or belts are always visible, with a good telescope. They are continually changing their form and position. Some of these belts are from five to ten thousand miles in breadth, and

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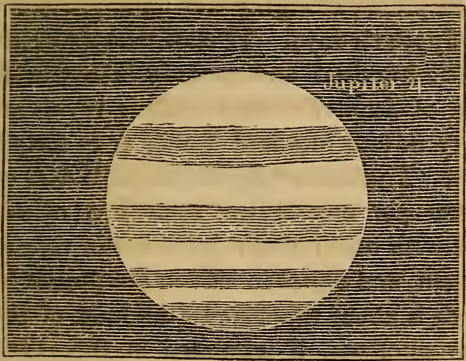
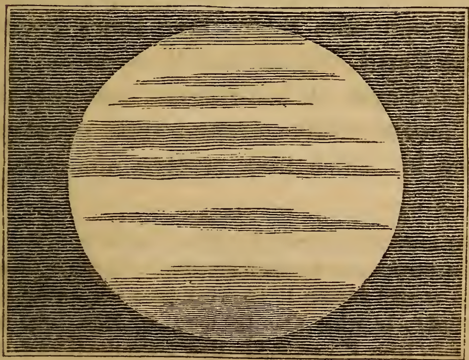
What have some astronomers said respecting the temperature at the poles of this planet? What arrangements are probably made? What fact is evidence of a peculiar arrangement to reflect light and heat? Has Jupiter an atmosphere? What is Lardner's opinion? What aspect does the surface of Jupiter present? What are those dark belts supposed to be? Are these belts changeable or unchangeable? How long are any of them?

more than one hundred and thirty miles in length. These zones or belts are almost invariably parallel with the equator of the planet, and though sometimes for several months they exhibit no variation, yet at other times a belt has disappeared and a new belt been formed in less than two hours. The diagrams exhibit the general appearance of these clouds or belts, as seen through the telescope.





In what direction do these belts run? How long do they ever remain permanent? How rapidly do they ever change?

Jupiter has four moons. They have received the names, in the order of their distance from the planet, of Hebe, Ganymede, Themis and Metis. These names are, however, but little used. The satellites are generally distinguished by the order of their distance, the one nearest Jupiter being called the first. Hebe revolves around Jupiter in forty-two hours, that is, in about four of Jupiter's days. Ganymede revolves around the planet in eighty-five hours, or in eight and a half of Jupiter's days. Themis completes its revolution in one hundred and seventy hours, or in about seventeen of Jupiter's days. Metis revolves around its primary in four hundred hours, or in forty of Jupiter's days. The first of Jupiter's satellites is a quarter larger than our moon; the second is of about the same size with ours; the third is seven times as large as our moon, and equal in size to the planet Mercury. The fourth is about three times the bulk of the moon. All these satellites, if inhabited at the rate of two hundred and eighty inhabitants to a square mile, would support a population thirty-three times greater than that of this Earth. These satellites can never be seen by the naked eye. It is a singular fact that they all, like our moon, revolve around their primary in the same time in which they revolve upon their axes.

How many moons has Jupiter? What names have they received? How are the moons usually distinguished? In what time does the first revolve around Jupiter? In what time the second? In what time the third? In what time the fourth? How large is the first satellite? How large the second? How large the third? How large the fourth? What population would all these satellites support? Can these satellites be seen by the naked eye? What singular fact is ascertained respecting the satellites of Jupiter?

The first satellite is two hundred and sixty-two thousand miles from Jupiter; the second, four hundred and twenty-three thousand; the third, six hundred and seventy-six thousand; and the fourth, one million one hundred and eighty-nine thousand.

It was by means of the eclipses of the satellites of Jupiter, that the progressive motion of light was discovered. If the motion of light were instantaneous, we should see an eclipse of one of Jupiter's satellites, as soon, when the planet is at its farthest distance from the Earth, as when it is nearest to us. When the Earth is at its greatest distance from Jupiter, it is about two hundred millions of miles farther from the planet, than when the two planets are nearest to each other. And it is found, that an eclipse can be seen about a quarter of an hour sooner, when the planets are nearest together, than when at their greatest distance. It follows that light, requiring a quarter of an hour to traverse a distance of two hundred millions of miles, moves at the rate of about two hundred thousand miles a second. When one of the satellites of Jupiter disappears from an observer on the Earth, as it goes behind the planet, it is said to be occulted or hidden. When it comes between Jupiter and the Earth, thus apparently

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What distance is the first satellite from Jupiter? What distance the second? What distance the third? What distance the fourth? What discovery has been made by means of the satellites of Jupiter? What would result if the motion of light were instantaneous? How much farther is Jupiter from the Earth at its greatest than at its nearest distance? How much sooner can an eclipse be seen when the planets are nearest than when at their greatest distance? With what speed does this show light to move? When is a satellite of Jupiter said to be occulted or hidden?

passing over the surface of the planet, it is said to transit the disc of its primary. The nocturnal scenery to an inhabitant of Jupiter must be beautiful in the extreme. These brilliant moons are continually passing, with great rapidity, through the heavens—sometimes all four shining in the firmament together, exhibiting a constant succession of eclipses, changes and occultations. An observer upon Hebe, the satellite nearest to Jupiter, would behold the enormous globe of Jupiter suspended in the heavens above him, appearing fifteen hundred times larger than the full moon does to us, and filling nearly the whole firmament with its vast magnitude. It is a sublime idea, that this wonderful globe, peopled perhaps with countless millions, is revolving upon its axis at the rate of twenty-eight thousand miles an hour, and circling in its majestic orbit, with its accompanying retinue of four revolving worlds, with the speed of five hundred miles every minute.

When is a satellite said to transit its primary? How large would Jupiter appear to an inhabitant of Hebe? With what rapidity does Jupiter revolve upon its axis?

CHAPTER V.

SATURN—HERSCHEL OR URANUS.

SATURN.

Though Jupiter is the largest planet in the Solar system, Saturn is, on many accounts, the most magnificent and interesting. This planet appears very small to the naked eye, and shines with a feeble light, in consequence of its immense distance from the Sun. Saturn is nine hundred millions of miles distant from the Sun; a distance which it would take a cannon ball, at its greatest velocity, two hundred and fifteen years to traverse. This planet is about eighty thousand miles in diameter. In bulk it is about one thousand times larger than the Earth. It would contain a population seven thousand times greater than the Earth. Though Saturn moves in its orbit at the rate of twenty-one

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What is considered the most interesting planet in the Solar system? How does Saturn appear to the naked eye? Why does it shine with such feeble light? How far is Saturn from the Sun? How long would it take a cannon ball to traverse that distance? What is the diameter of Saturn? How does its bulk compare with that of the Earth? What population would Saturn sustain? With what speed does Saturn revolve in its orbit?

thousand miles an hour, it requires thirty of our years for it to perform its circuit around the Sun. Its diurnal revolution is performed in ten hours and a half. Consequently the days on Saturn, are but ten and one half hours in length; while a year upon that planet is equal to thirty of ours. Saturn has seven satellites. They can, however, only be seen with the most powerful telescopes, as the planet is at such an immense distance from the Earth. The diameters of the satellites of Saturn have never yet been accurately measured. Four of the moons of Saturn revolve nearer the planet than is our moon to the Earth, and they appear, to an observer on Saturn, from twice to ten times as large. The largest of the moons of Saturn is at the greatest distance from the planet. Each of these moons probably revolves upon its own axis, in the same time in which it revolves around its primary. The nearest satellite is but eighty thousand miles from the planet, and probably appears at least ten times larger than our moon. The second satellite, being but one hundred and twenty thousand miles distant, and undoubtedly as large, at least, as our moon, must present to

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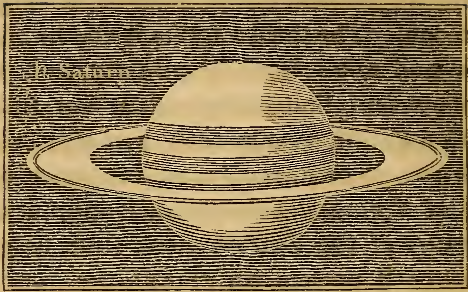
In what time does Saturn revolve around the Sun? In what time is its diurnal revolution performed? How long is a day upon Saturn? How long a year? How many moons has Saturn? Are these moons visible to the naked eye? What is said of the diameter of Saturn's satellites? How many moons are nearer Saturn than our moon is to the Earth? How large do these moons appear to an inhabitant of Saturn? Which moon is at the greatest distance from the planet? In what time do these moons probably revolve upon their axis? What is the distance of the nearest satellite from Saturn? How much larger does this satellite probably appear than our moon? At what distance is the second satellite from Saturn? How large is this satellite?

an observer on Saturn, a disk four times larger than our full moon. The third satellite is one hundred and sixty thousand miles from its primary, and probably appears about four times larger than our full moon. The fourth and fifth moons, each, probably, about the same size as our own, revolve at a distance of about two hundred thousand miles from its primary. This is the distance of the Earth's moon from its primary. They must each present an appearance very similar to that of our moon. The sixth and seventh, though probably much larger than our moon, yet revolving at a much greater distance from their primary, appear a little smaller than ours does, at the Earth. The heavens must, indeed, appear gorgeously illumined at midnight, as an observer on Saturn looks at this splendid retinue of moons, suspended above him, and most of them passing through all their changes, in from two to seven days. The moons of Saturn are usually designated in the order of their discovery, and not in the order of their distance from the primary.

The most remarkable peculiarity belonging to this planet is that it is surrounded by several stupendous rings. The number of these rings is not with certainty ascertained. Two of them are very conspicuous.

How much larger will it appear than our moon? What is the distance of the third satellite from its primary? How large does it appear? What is the probable size of the fourth and fifth satellites? At what distance do they revolve from their primary? What appearance do they present to the inhabitants of Saturn? How do the sixth and seventh moons appear? In what time do most of these moons pass through their changes? In what order are the moons of Saturn generally designated? What is the most remarkable peculiarity belonging to this planet? What is the number of these rings? How many are conspicuous?



These rings of vast magnitude entirely encircle the planet. They are evidently of a solid, compact substance, essentially similar to the body of the planet itself. They are unquestionably worlds of this peculiar form, with mountains and vales, and peopled with millions of intelligent beings. The distance between the first ring and the body of the planet is about thirty thousand miles, so that four globes as large as our Earth could be placed between them. With the telescope, stars are easily discernible as you look through the space between this ring and the body of the planet. And this conclusively proves the separation of the ring from the body of the planet. The breadth of this first or interior ring is seventeen thousand miles, which is more than twice the diameter of the Earth. And this ring encircles a space sufficiently large to contain three hundred and forty globes of the size of the Earth. The diameter of this ring is more

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What is the nature of these rings? What is the distance between the body of the planet and the first ring? What proves the separation of the ring from the body of the planet? What is the breadth of the first ring? How large a space does this ring encircle? What is the diameter of this ring?

than one hundred and fifty thousand miles. It would require seventy years for a person to travel over its outer circumference at the rate of twenty-five miles a day. This ring is about one hundred miles in thickness. About two thousand miles from this inner ring is an outer ring, about ten thousand miles in breadth and more than five hundred thousand miles in circumference. These two rings, in extent of surface, are nearly one hundred and fifty times larger than the Earth. They would sustain a population more than ten thousand times the present population of our globe. These concentric rings—themselves enormous worlds—are circling around their primary with the amazing velocity of about one thousand miles a minute. They revolve around Saturn in the same time in which Saturn revolves upon its axis. The wisdom of God is conspicuously displayed in the nice adjustments with which these vast worlds career onward in their endless orbits, with no interference. Recent observations, made at Rome, render it probable that, instead of there being only two rings, there are seven independent rings, but with spaces so small between them, that the separation can only be distinguished with the most powerful telescopes.

These rings reflect the Solar light with peculiar

How long would it take to traverse its circumference, at the rate of twenty-five miles a day? What is the thickness of Saturn's ring? What is the distance between the inner and the outer ring? What is the breadth of the outer ring? What is the circumference of the outer ring? How much larger are these two rings than the Earth? What population would they support? With what velocity do these rings revolve? In what time do they revolve? How many rings is it now supposed that there are?

splendor, and consequently they must present a very magnificent appearance to the inhabitants of Saturn. In the day-time they will present the aspect of a light cloud, clearly defined, girdling the heavens; but as the Sun goes down, this broad band will increase in brilliancy, encircling the sky with its effulgence, illuminating the planet with almost noon-day light. As the inner ring is so near the planet Saturn, being but one-eighth part of the distance of our moon from the Earth, the inequalities of the surface of the ring must be easily discernible. Even with our telescopes, at such a distance, could easily be discerned many of the operations of their inhabitants. And these rings will be seen revolving with such rapidity, that any given point will ascend from the equator to the zenith in two hours and a half. It is a pleasing thought that if we, here on earth, are truly the disciples of the Redeemer, when death shall call us away, we may be permitted to visit these gorgeous worlds, scattered in infinite variety of form and beauty through the depth of space, there to admire their indescribable grandeur of scenery, and to share the joys of their happy inhabitants.

HERSCHEL.

The planet Herschel was discovered in the year 1781, by Sir W. Herschel. As it was discovered in the reign of George III. of England, the illustrious

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How will these rings appear in the day-time? How in the night? How will the distance of the inner ring compare with that of the Moon from the Earth? What pleasing thought is suggested? When was the planet Herschel discovered?

discoverer gave it the name of Georgium Sidus, or Georgian Star. Others named it Uranus, as Uranus was the father of Saturn, Saturn the father of Jupiter, Jupiter the father of Mars. Columbus has been robbed of the honor of giving the new world his name. The illustrious discoverer of this new planet ought not to be in a similar way defrauded.

Herschel is probably the most distant planet of the Solar system. There may, however, be others not yet discovered. Its distance from the Sun is eighteen hundred millions of miles. In a very clear night this planet can be discerned by the naked eye. Its distance from the Earth may be faintly imagined, from the fact that a carriage, travelling at the rate of twenty miles an hour, would occupy nearly ten thousand years in passing from this Earth to the planet. Herschel revolves in its orbit at the rate of fifteen thousand miles an hour, and yet it is eighty-one years in performing the vast circuit. Though the planet was discovered several years before the commencement of the American Revolution, it has not yet accomplished one revolution around the Sun since its discovery. Though the length of the year upon Herschel has been perfectly ascertained, the length of its day is not yet known. Herschel is at such an im-

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What name did Herschel give the planet? What name have others given the planet? Why has it been called Uranus? Is Herschel the most distant planet? Can it ever be seen with the naked eye? What is the distance of Herschel from the Sun? How long would it take a carriage, moving twenty miles an hour, to pass from the Earth to Herschel? With what speed does Herschel revolve? In what time does it revolve around the Sun? What is the length of a year upon Herschel?

mense distance from the Earth that the time of its rotation upon its axis has not yet been ascertained. That it does rotate is a matter of inference, and not of observation.

The diameter of Herschel is about thirty-five thousand miles. It is about eighty-one times larger than the Earth. It would sustain a population nearly fourteen hundred times greater than the present population of the globe. Herschel is at such an immense distance from the Sun, that that luminary must appear to its inhabitants about as large as Venus does to us. The Sun, however, shining not by reflected light, emits rays so brilliant as to give the inhabitants light fully equal to a cloudy day upon Earth, even if the constitution of the atmosphere of Herschel is similar to our own. There is probably, however, a peculiar constitution of the atmosphere, to promote the reflection of light and heat in a manner adapted to the remote situation of the planet from the Sun. The darkness of the night is cheered by rays reflected from six moons, which revolve around the planet. The fact that Herschel is so far from the Sún is no evidence that it is peculiarly cold upon that planet. The degree of heat is not in proportion to the distance of a body from the Sun. Even upon the equator a mountain elevation of fifteen thousand feet brings one to

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What is the diameter of Herschel? How large does the Sun appear to the inhabitants of Herschel? How much larger is Herschel than the Earth? How light would this make a day upon Herschel? What peculiar constitution of the atmosphere may probably be adopted? How is the darkness of the night cheered? Is it necessarily very cold upon Herschel? At what elevation on the equator is perpetual snow?

the region of perpetual snow. There may be, consequently, some arrangement by which the warmth of our central luminary may fall as genially upon the hills and valleys of Herschel as upon the verdant slopes of sunny Italy. It is highly unphilosophical to suppose that upon all the planets the constitution of Nature is the same. Intelligent beings, of far different bodily structure and wants from the inhabitants of the Earth, probably rejoice in the dwellings of those gorgeous creations of the Deity.

The magnitude of the satellites of Herschel has never yet been precisely ascertained. It is probable, however, that these satellites are considerably larger than our moon, else they could hardly be seen, even with the telescope, at such a vast distance from the Earth. If these six moons are three thousand miles in diameter, they will sustain, unitedly, a population of more than sixty times as many as now dwell upon the Earth. It is a remarkable peculiarity in these satellites, that they all revolve around their primary from east to west, while every other primary and secondary satellite in the Solar system revolves around its central body in an opposite direction—from west to east.

If all the planets of the Solar system were inhabited as densely as the island of Great Britain, they would sustain a population more than twenty-seven thou-

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What is said respecting the constitution of nature upon the several planets? What is said of the magnitude of Herschel's satellites? What is their probable magnitude? What population will the moons of Herschel probably sustain? What remarkable peculiarity is there in the revolution of these satellites? How large a population will all the planets of the Solar system sustain?

sand times greater than now peoples the Earth. And yet, the Sun is five hundred and forty-five times larger than all these planets taken together. And it is supposed that this immense globe, with all its retinue of revolving worlds, is flying through space at the rate of sixty thousand miles an hour, circling around some distant and unknown centre which no telescope has ever yet revealed to human eyes. It has been well said, that "an undevout astronomer is mad." Who can contemplate these sublime ideas and not look forward with interest to the hour when the liberated soul may soar amid these wonderful orbs? And, in view of this blessedness—doubtless reserved for the humble disciple of Jesus—who can refrain from breathing the prayer, "Oh! that I may die the death of the righteous!"

What is the comparative size of the Sun? How rapidly is the Sun supposed to be moving?

CHAPTER VI.

COMETS.

THERE is connected with the Solar system, besides the planets, a large number of mysterious bodies, called *Comets*. Comets are bodies having no definite shape, and consisting mainly, not of solid, but vaporous or aeriform substance, which usually appear unexpectedly in our system, and rushing, with great velocity, around the Sun, again disappear in the depths of space. The meaning of the word Comet, is a *hairy star*. They are so called because they are usually accompanied by a long train resembling luminous hair.

Respecting the *physical constitution* of Comets but little is known. They usually consist of three parts. The first is a brilliant spot called the nucleus. This is probably a highly condensed gaseous or vaporous substance. The nucleus may, in some cases, be solid; but that this is not usually the case is evident from the fact, that stars can be often seen through the nucleus. The nucleus is generally surrounded by a hazy or nebulous covering, called the *envelope*, or *coma*. And there is usually connected with this nucleus a long

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What is connected with the Solar system besides planets? What are Comets? What is the meaning of the word Comet? Why are they so called? What is said of the physical constitution of Comets? Of how many parts do they usually consist? What is the first? What is the nucleus? What is the evidence that it sometimes is not solid? With what is the nucleus generally surrounded?

fan-like appendage, called the *train* or tail. The en-

velope and train are always composed of a substance somewhat resembling the thinnest fog. The interposition of this exceedingly rare substance, though perhaps a hundred million of miles in thickness, does not obstruct the rays of light twinkling from the feeblest

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What other part is generally connected with the nucleus? Of what is the envelope or train composed? What is said of the density of the train of a Comet?

star. Newton, indeed, has expressed the opinion, that this luminous haze is so inconceivably rare, that if the tail of the largest Comet which was ever seen, were compressed to the consistency of atmospheric air, it would not occupy, in bulk, the space of one cubic inch. Whether, in *any case*, the nucleus of a Comet is solid, is a question not yet decided. Comets vary so much in appearance, that while some have no nucleus, others have no train or tail. Those Comets without a train are usually called *bearded comets*. One may be seen illustrated in the accompanying diagram.

What opinion has Newton expressed? Is the nucleus ever solid? What is said of the variety in the appearance of Comets? What are bearded Comets?

Comets do not permanently remain the same, but are often changing their appearance, sometimes as rapidly and fantastically as the northern lights.

Comets vary exceedingly in size. While some present themselves, merely as a tuft of down upon the sky, others sweep, with their enormous trains, millions of miles through the immensities of space, extending with their pale and portentous glare from the zenith to the horizon. Some Comets are seen with a nucleus but twenty-five miles in diameter, while others have a nucleus many thousand miles in diameter. The tail of a Comet which appeared in the year 1811, was estimated to be one hundred and thirty-two millions of miles in length, its nucleus was fifty thousand miles in diameter, and the nucleus, with the envelope, nine hundred and forty-seven thousand miles in diameter, which is larger than our Sun. Most Comets are only visible through the telescope.

The *number* of Comets which have visited the Solar system, is estimated to be as many as seven millions; others have calculated the number to exceed five hundred millions. But a few hundred, however, of these have been seen by the inhabitants of the Earth. Seven or eight hundred only have been observed since the commencement of the Christian Era. They suddenly burst upon our view, rushing into our system from

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What is said of the changes in the appearance of Comets? What is said of the size of Comets? How small is the nucleus of any Comet? How large is any? How long was the train of the Comet of 1811? What was the size of its nucleus? What the size of the nucleus with the envelope? What is said of the number of Comets which have visited our system? In what direction do they come?

every conceivable direction, revolving in various kinds of orbits, with different degrees of velocity, some approaching very near the Earth, and others not coming within millions of miles of our orbit.

The time required in the *periodic revolution* of Comets is very various. The three Comets whose orbits have been measured, and whose periodic return have been satisfactorily established, are Encke's, Halley's, and Biela's. They are so named from distinguished philosophers who calculated their periods. Encke's Comet performs its revolution in three years and a half. Its orbit does not extend beyond the verge of the Solar system. This Comet is very small, has no tail, and is invisible to the naked eye. Halley's Comet performs its revolution in seventy-five years. It is very large, and distinctly visible to the naked eye. It rushes in an exceedingly elongated orbit, to the distance of two thousand millions of miles beyond the orbit of Herschel. This Comet made its last appearance in 1835, and is now rushing along its almost limitless pathway, not again to appear in our evening sky until the year 1910. Biela's Comet completes its revolution in a little less than seven years. Other Comets are supposed to revolve in orbits, which it re-

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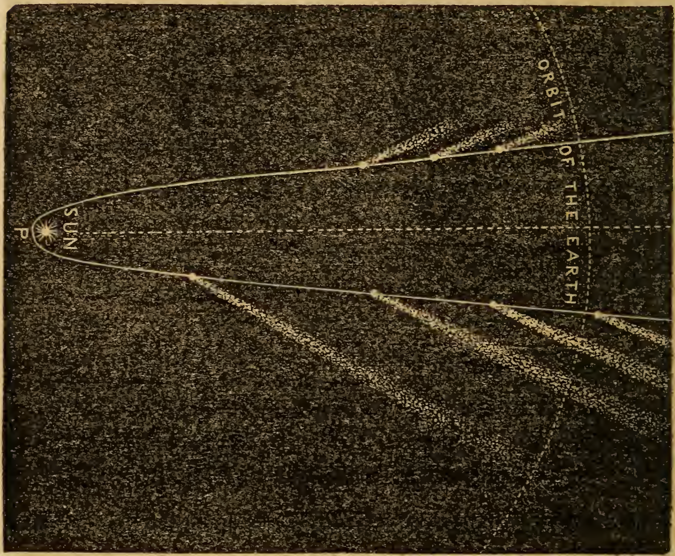
What is their speed? How near do they approach the Earth? What three Comets have had their periodic returns calculated? In what time does Encke's Comet revolve in its orbit? How far does its orbit extend? What is the size of this Comet? Is it visible to the naked eye? In what time does Halley's Comet perform its revolution? What is the size of this Comet? Is it visible to the naked eye? How far does its orbit extend? When did this Comet make its last appearance? When will it again appear? In what time does Biela's Comet perform its revolution? What is said of other Comets?

quires several thousands of years to traverse; while others visit our system, and depart never to return. The following diagram will show the elongated form of the orbit of a Comet.



The purposes which Comets are intended to subserve are entirely unknown. Various suppositions have been suggested by Astronomers, but none of them have obtained any general approval. Sir Isaac Newton has expressed the opinion, that Comets were intended to replenish Suns with the light and heat they lost by radiation. Others have supposed that they were embryo worlds, which, in process of time, by union and

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What purposes do Comets subserve? What opinion has Sir Isaac Newton expressed? What opinion have others expressed?

consolidation, would form new suns and planets. These are, however, merely conjectures.

Whether Comets shine by their own light, like suns, or by reflected light, like the planets, has been long undecided.

Do Comets shine by their own or reflected light?

CHAPTER VII.

THE FIXED STARS.

Having thus briefly examined the several bodies which compose the Solar system, we will now turn our attention to the Fixed Stars, which we see twinkling in the depths of space above and around us.

THE NUMBER OF FIXED STARS.

The number of Fixed Stars visible to the naked eye in a clear night is about one thousand. By the aid of the telescope innumerable other stars are brought into view, so that more than one hundred millions of these gorgeous suns, each unquestionably surrounded by its retinue of worlds, are distinctly seen. If we suppose that each of these suns is accompanied only by as many planets as are embraced in our Solar system, we have three thousand millions of worlds in our own firmament. No human mind can form a concep-

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To what is the attention now to be directed? How many fixed stars are visible to the naked eye? How many are visible through ordinary telescopes? How many worlds are there probably in our firmament?

tion of this number; but even these, as will hereafter be shown, form but a minute and comparatively insignificant portion of that boundless empire which the Creator has reared, and over which he reigns. Eternal ages may glide joyfully along, as the Christian explores these wonderful worlds, of every variety of form and character, and partakes of the hospitalities of their blissful inhabitants. It is pleasant to tread the pavements of a foreign city—to traverse the glaciers of the Alps—to glide over the surface of the Nile in the midst of the mouldering memorials of its past grandeur; but what are all these, compared to the journey of a rejoicing spirit to these sublime mansions of the Deity?

CONSTELLATIONS.

That the stars may be more easily distinguished from each other, and their places in the heavens defined, the ancients have divided them into groups or clusters, called constellations. These constellations have been very fancifully named after some animal or object, which it is supposed might be easily delineated in the space which the group occupies. When, however, we look upon the celestial globe or upon the starry heavens, we can scarcely discern any resem-

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What is said respecting the conception of such numbers? What is said respecting the comparative importance of these worlds? What pleasant thought does this introduce to the Christian? By whom were the stars arranged into clusters called constellations? Why was this done? How were the constellations named? Can any resemblance be traced between the figures of the constellations and the objects whose names they bear?

blance between the actual figure of the groups of stars and the objects whose names they bear; and the endeavor to trace out any resemblance only embarrasses the mind. The number of constellations into which the visible stars have been arranged is ninety-three. Of these, thirty-four are in the northern firmament, and forty-seven in the southern firmament, and also twelve in that portion of the heavens called the Zodiac.

The zone called the Zodiac is sixteen degrees broad. The apparent path of the Sun, and the orbits of all the planets except three of the Asteroids, are within this zone. This zone is divided into twelve equal parts, called the twelve signs of the Zodiac. The *signs* of the Zodiac and the constellations of the Zodiac, possessing a common name, had doubtless formerly a common origin. About two thousand years ago the signs and the constellations were probably together. They now, however, vary about thirty degrees. The Sun enters the sign of

1. *Aries* ♈, the Ram, the 20th of March;
2. *Taurus* ♉, the Bull, the 20th of April;
3. *Gemini* ♊, the Twins, the 21st of May;
4. *Cancer* ♋, the Crab, the 21st of June;
5. *Leo* ♌, the Lion, the 23d of July;
6. *Virgo* ♍, the Virgin, the 23d of August;
7. *Libra* ♎, the Balance, the 23d of September;

How many constellations are there? How many of these are in the northern firmament? How many in the southern firmament? What is the breadth of the Zodiac? What heavenly bodies move within this zone? Into what is this zone divided? When were the signs and constellations probably together? How much do they now vary? At what time does the Sun enter the several signs?

8. *Scorpio* ♏, the Scorpion, the 23d of October;
9. *Sagittarius* ♐, the Archer, the 23d of November;
10. *Capricornus* ♑, the Goat, the 23d of December;
11. *Aquarius* ♒, the Waterman, the 20th of January;
12. *Pisces* ♓, the Fishes, the 19th of February.

As the first six of these signs lie on the north side of the equator, they are called the northern signs. The remaining six, being on the south side of the equator, are called the southern signs. The signs Capricornus, Aquarius, Pisces, Aries, Taurus, Gemini, are called *ascending signs*, because the Sun is then apparently advancing from the equator towards the north pole; and Cancer, Leo, Virgo, Libra, Scorpio, Sagittarius, are called *descending signs*, as the Sun is retiring from the north pole as it passes through them. The path which the Sun appears to traverse through the heavens is called the ecliptic. The point where the Sun crosses the equator moves back about fifty seconds of a degree each year, and in about twenty-six thousand years this point will have moved entirely round the equator. This backward movement of the point where the ecliptic and the equator intersect each other, is called the Precession of the Equinoxes.

This division of the stars into constellations is of very ancient date. Job refers to some of these constellations by the names which they now bear.

What are the northern signs? What are the southern? What are the ascending signs? What are the descending signs? What is the ecliptic? How far does the point where the ecliptic and the equator intersect each other move each year? What is the Precession of the Equinoxes?

MAGNITUDE OF THE STARS.

It is impossible to determine with precision the real magnitude of the fixed stars. Their distance is so immense, that though we take the whole diameter of the earth's orbit as a base-line, from either end of this line the star still seems in the same position. The diameter of the earth's orbit is about two hundred millions of miles; and this vast line is an almost microscopic point, when compared with the interminable expanse which intervenes between the eye and yonder twinkling star. No power of the telescope will cause the stars to assume any apparent diameter. They appear through the most powerful instruments as mere points of the most piercing brilliancy. From various calculations, it is evident that none of the stars are smaller than our sun; and it is probable that many of them are far superior to the Sun in magnitude and splendor.

Dr. Wollaston has inferred, from arguments founded upon the intensity of light, the star Sirius to be at least fourteen times larger than our sun; and Sir William Herschel has estimated the star Vega to surpass in magnitude fifty-four thousand globes as large as the

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What is said of the real magnitude of the fixed stars? What fact illustrates their immense distance? What is the diameter of the Earth's orbit? Have the fixed stars any apparent diameter? How do they appear through the most powerful telescopes? How small are any of them? What is the apparent magnitude of some? What is said of the star Sirius? Upon what is this opinion founded? What is Herschel's opinion of the size of the star Vega?

Sun. The Sun is more than five hundred times greater than all the planets and satellites of our system united. Of such magnitude it is impossible for the human mind to form any conception. How utterly inconceivable is a globe fifty-four thousand times greater than the Sun. When we look upon these twinkling lights, and imagine the variety of structure and scenery with which they abound, and think of the myriads of lofty intelligences with which they are undoubtedly peopled, how greatly does it enlarge our ideas of the grandeur of the Creator's works. During all the revolutions of an interminable existence, the Christian will ever find an inexhaustible supply of objects for sublime and delighted contemplation.

The stars are also divided by astronomers into different classes, called magnitudes. They are guided in this classification by the comparative brilliance with which the stars shine. The most brilliant are called stars of the *first magnitude;* those a little less brilliant of the *second*, and so on to the sixth magnitude. The smallest stars visible to the naked eye are called those of the *sixth magnitude.* With the use of the telescope the classification is still carried on to stars of the twentieth magnitude.

What is said of the magnitude of the Sun? What moral reflection does this subject suggest? How are the stars classified by Astronomers? What are the most brilliant stars called? What are the smallest visible to the naked eye called? How far is the classification carried?

VARIETY IN THE STRUCTURE OF THE STARS.

On this globe we find great variety in the works of the Creator. As we raise our eyes to the Solar system, we perceive there a similar display of the profusion of creative power. Jupiter rolls along his majestic pathway, encircled by belts and accompanied by his beautiful household; and Saturn, with his gorgeous rings, rushes through his almost boundless orbit; and comets —ethereal and spiritualized worlds—come careering onward through the depths of space, adapted for the residence of beings of whose structure and nature we can form no idea; and the Sun, with its unchanging heat and its eternal day, adds still new variety to this scene of grandeur. As we leave the Solar system and wing our flight to that vast profound where the fixed stars repose, we behold indications of still continued variety, not only in the magnitude of those orbs, but also in their internal structure. When these stars are examined through powerful telescopes, they assume a great variety of colors. One appears of a brilliant orange color, another green, another blue, another red. There is undoubtedly a vast diversity in respect to magnitude. As one single drop of water affords a home for myriads of living creatures, where they may revel in an expanse to them apparently limitless, so

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What is said of the works of the Creator on this globe? What is said respecting variety in the Solar system? What is Jupiter's appearance? What is the appearance of Saturn? What is said of comets? What variety is perceived in the fixed stars? How do they appear through powerful telescopes?

there may be globes even of microscopic diminutiveness, peopled by busy millions, who there find, for them, an almost boundless domain; while other orbs may swell out to an interminable grandeur, compared with which our sun itself dwindles into an insignificant point. Some of the stars shine with their own light, while there may be others, of equal magnitude, invisible to us because illuminated only by rays from distant luminaries. Many of these vast orbs are solid, material worlds; and there are others, of a magnitude surpassing all powers of the imagination to conceive, which are gaseous or ethereal in their nature, adapted probably for the residence of beings of whose nature we can form no conception. But in the interminable expanse of these immaterial worlds, spreading for countless myriads of miles through these immensities, beings allied to cherubim and seraphim may raise their ceaseless and exulting hosannas.

DISTANCES OF THE STARS.

The distance of the Sun from the Earth, and of the various planets which compose our Solar system from the Sun, and from each other, has been measured with much accuracy; and those distances are so enormous that no human mind is capable of comprehending them. No mind can embrace the idea of a single million; but the Sun is ninety-five millions of miles

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What is said respecting variety in magnitude? In what respect may the stars differ in structure? What distances in the heavens have been accurately measured? Can these distances be comprehended?

from the Earth. Though we cannot tell how far the fixed stars are from the Earth, it is susceptible of demonstration that none of them can be nearer than twenty billions of miles. Some faint conception of this distance may be acquired from the statement that a cannon ball, flying five hundred miles an hour, would require four millions, five hundred and ninety-five thousand years before it could pass that distance. While it is certain that none of the fixed stars are nearer the Earth than the distance thus stated, from various calculations it is estimated that the star 61 Cygni is at such a distance from the Earth, that a steam carriage, moving with the velocity of four hundred and eighty miles a day, would require more than three hundred and fifty millions of years in passing from this Earth to the star. And yet there are many stars revealed by the telescope which must be several thousand times farther distant than 61 Cygni. And though these numbers and ideas bewilder the mind, these distances are but minute and indivisible points, compared with that vast infinity of space which the Creator has crowded with worlds. The numbers which can be embraced within the reach of the telescope are probably insignificant in comparison with the majestic whole.

At what distance is the Sun from the Earth? Can the distance of the fixed stars from the Earth be measured? What fact respecting their distance is susceptible of demonstration? What illustration is given of the distance of twenty billions of miles? What is said of the distance of the star 61 Cygni? What is said of other stars still more remote? What proportion of the stars is probably embraced within the reach of the telescope?

NEW STARS AND LOST STARS.

There must have been a time when each star was created. Whether the formation of the stars was a gradual or a sudden process, we cannot determine; but since the Christian era there have been several instances in which stars have suddenly appeared in the sky, as if they had just been launched forth fresh from the Creator's hand. In November, 1572, a very brilliant star suddenly appeared in the constellation Cassiopeia. This star was so brilliant as to attract general attention, and was even visible at noon-day. It continued to shine with gradually diminishing lustre for about sixteen months, when it disappeared. This star was far beyond the planets, in the region of the fixed stars. The cause of its sudden appearance, and of its gradual disappearance, is of course involved in profound obscurity. Some have supposed that it was the conflagration of some distant world, whose rays were thrown across the vast abysses of space to gleam upon human eyes. Others have supposed that it was some vast sun circling in its majestic orbit, and that it was visible in its nearest approach to the Earth, and that it gradually vanished again as it retired. This, however, would hardly account for its *sudden* appearance.

In the year 1804 a new star appeared in the con-

Have the stars existed from eternity? Was each one suddenly or gradually created? What is said respecting the appearance of new stars? Describe the new star of 1572. To what cause have some attributed the appearance of this star? To what cause have others attributed its appearance?

stellation Serpentarius. It shone with a brilliancy surpassing that of any of the fixed stars; and, what was very remarkable, it was continually changing into all the colors of the rainbow. This star also gradually disappeared in about a year. It was in the region of the fixed stars, and continued apparently immovable in its position. Says Mrs. Sommerville, "It is impossible to imagine anything more tremendous than a conflagration that would be visible at such a distance." Says Dick, "There was a splendor concentered in that point of the heavens where the star appeared, more than equal to the blaze of twelve hundred thousand worlds such as ours, were they all collected into one mass and all at once wrapt in flames. Nay, it is not improbable that, were a globe as large as would fill the whole circumference of the Earth's annual orbit to be lighted up with a splendor similar to that of the Sun, it would scarcely surpass in brilliancy and splendor the star to which we refer."

Says La Place, "As to those stars which suddenly shine forth with a very vivid light and then vanish, it may be supposed, and with probability, that great conflagrations, occasioned by extraordinary causes, take place on their surfaces; and this supposition is confirmed by their change of color, analogous to that which is presented to us on the Earth by bodies which are consumed by fire."

In what constellation did the star of 1804 appear? What is said of its brilliancy? What remarkable appearance did it assume? How long was this star visible? Where was its position? Repeat Mrs. Sommerville's remark. Repeat Dick's remark. Repeat the remark of La Place.

Says Dr. Mason Good, "What has befallen other systems will assuredly befall our own. Of the time and the manner we know nothing; but the fact is incontrovertible—it is foretold by revelation—it is inscribed in the heavens—it is felt through the Earth." The Word of God has informed us that "the elements shall melt with fervent heat, and the Earth and the works that are therein shall be burned up." It is, however, to be remembered that combustion is not annihilation. After the conflagration of this globe, the particles of which it is composed will remain as before, only changed in their combinations; and from the ruins there may be created a new earth, wherein shall dwell righteousness. "Within the last century," says Dick, "no less than thirteen stars in different constellations seem to have totally perished, and ten new ones to have been created."

VARIABLE STARS.

Those stars are called variable, which have periodic changes in their apparent magnitude and brilliancy; at one time shining with great splendor, and then gradually fading away, till they become quite dim or entirely disappear. About thirty-seven such stars have been discovered. Some of these stars pass through these periodic changes in about a year. Others disappear, and

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Repeat the remarks of Dr. Mason Good. Repeat the quotation from the Bible. What will remain after the final conflagration? How many stars have apparently been destroyed within the last century? How many new ones have been formed? What are variable stars? How many variable stars have been discovered? In what time do some of these pass through their periodic changes?

are not again visible for several years. One remarkable star in the constellation Perseus, is continually passing through the changes, from a star of the first magnitude to one of the fourth, in about two days and a half. It is very difficult to come to any satisfactory conclusion respecting the cause of this phenomenon. Various theories, however, have been proposed to account for these appearances.

FIRST THEORY.

Sir William Herschel suggests that one hemisphere of these globes may be covered with dark spots, or be less brilliant than the other, and that the revolution of the globe at one time presents the more luminous surface, and at another the less.

Clear Hemisphere. Spotted Hemisphere.

SECOND THEORY.

Again, it has been suggested that these variable stars may not be globes, but circles, like a grindstone in

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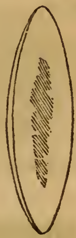
What is the case with others? What is said of a star in the constellation Perseus? What is the cause of this phenomenom? Describe the first theory. The second.

form; and, as they revolve, at one time the broad surface is presented to the eye, and again only the edge.

Side View.

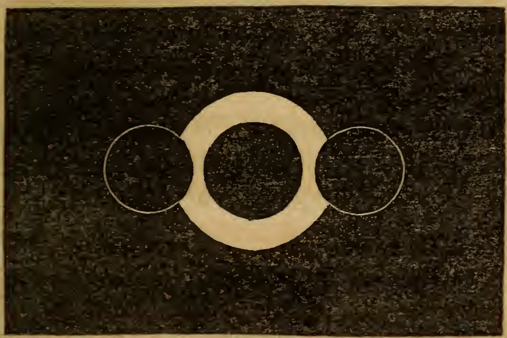
Edge View.



THIRD THEORY.

Again, it has been supposed that some large planet may be revolving around the luminary, and by the interposition of its opaque body, may cut off the rays of light.

The white globe in the cut represents a glittering star over whose surface a dark planet revolves periodically, diminishing its lustre.

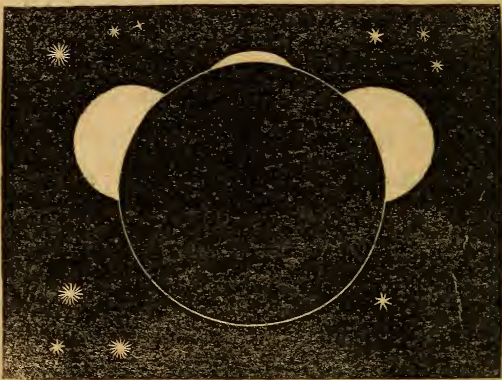


Describe the third theory.

FOURTH THEORY.

It is also suggested, as possible, that there may be planets of majestic size, vastly surpassing our sun in magnitude, around which a sun of lesser magnitude revolves, and that in its revolution it is periodically hidden behind the planet.

The dark globe in the cut represents a majestic planet, behind which its revolving sun gradually and periodically disappears.



FIFTH THEORY.

The phenomenon may be caused by a vast sun, "moving with inconceivable velocity in an immensely elliptical orbit, the longer side of which is nearly in a direction to our eye."

Let E be the Earth. The star revolves in the orbit A B C D, disappearing in the distance, as it passes towards the extreme of

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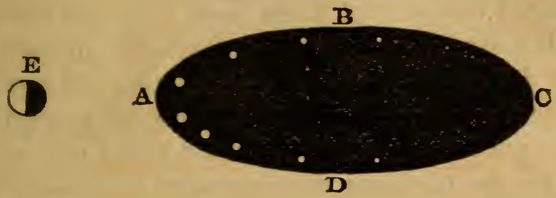
Describe the fourth theory. The fifth.

its orbit, at C, and shining with ever increasing lustre as it approaches A.



Whatever may be the cause, the fact of these variations is perfectly established, and the contemplation of the stupendous changes which must be occurring in those distant orbs, overwhelms the mind with amazement. Worlds vastly larger than our sun suddenly appear, and as suddenly disappear—now they blaze forth with most resplendent brilliancy, and again they fade away—and often are apparently blotted from existence. These worlds are unquestionably thronged with myriads of inhabitants. And the phenomenon which to us appears but as the waxing or waning lustre of a twinkling star, may to the dwellers on those orbs, be evolutions of grandeur, such as no earthly imagination has ever conceived. But these scenes, now veiled from human eyes, will doubtless all be revealed, when the Christian shall ascend on an angel's wing to the angels' home.

What is said of the *fact* of these changes? Describe the appearance of these variations. Are these worlds probably inhabited? How may the phenomenon appear to dwellers on those orbs? When will these scenes probably be revealed?

DOUBLE STARS.

As the planets revolve around the Sun, so it is ascertained that in very many cases two stars mutually revolve around each other. About six thousand of these double stars have been discovered, and carefully arranged in catalogues. These stars are generally so near each other, as to appear to the naked eye as one; but by the telescope they are seen to be separated. The periods of their revolutions have, in several cases, been ascertained.

A star revolves around the star Castor, in about three hundred and fifty years. In the constellation Virgo, there is a double star whose revolution is estimated to occupy about six hundred years. In the constellation Leo, there is a double star whose revolution occupies about twelve hundred years. These stars revolve in elliptical orbits, similar to those in which the planets revolve around the Sun.

The discovery of these double stars opens to the mind a new chapter in Astronomy. We here see suns revolving around suns, each unquestionably accompanied by its retinue of revolving worlds.

Though the apparent distance between these stars composing binary systems is so small, it is supposed that they are in reality separated by a distance as great

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What is meant by double stars? How many of these have been discovered? How do these stars appear to the naked eye? How do they appear through a telescope? What is known respecting their revolutions? What is said of the star Castor? What is said of the double star in the constellation Virgo? What is said of the double star in the constellation Leo? In what kind of orbits do these stars revolve? What is the probable distance between the stars which compose these systems?

as that between the Earth and any of these stars. The size of these bodies, visible at such an immense distance, must be enormous; and the velocity with which they are impelled in their stupendous orbits, must very far exceed that of any of the planetary bodies. The mind is elevated by the attempt to contemplate ideas of such grandeur.

COLORED SUNS.

"Many of the double stars," says Sir J. Herschel, "exhibit the beautiful and curious phenomena of contrasted or complementary colors. In such instances, the larger star is usually of a ruddy or orange hue, while the smaller one appears blue or green."

The scenery of a world illuminated to-day by a green sun, and to-morrow by an orange one, must be singular indeed. And this variety in the mansions of the Creator must contribute greatly to the enjoyment of those who may hereafter be permitted to wing their flight from world to world, and from star to star. These stars shine in nearly all the various colors of the rainbow. In the clear atmosphere of tropical climates, this variety in the color of the stars is quite perceptible to the naked eye. Stars also change their colors. Sirius was by the ancients called a red star; it is now brilliantly white.

What is said of the size and velocity of these revolving suns? What does Herschel say respecting the color of double stars? Of what color is the larger star generally? Of what color the smaller? What is said of the scenery of worlds thus illuminated? What various colors do the stars assume? How do these stars appear in tropical climates? Do stars ever change their color? What example of this is given?

TRIPLE AND MULTIPLE STARS.

In addition to binary systems, there are also triple, quadruple and multiple stars. And the various stars of which these systems are composed harmoniously revolve around each other. Such systems must be exceedingly complex. Unquestionably, each star, like our sun, is the centre of a system of planetary worlds, and each member of the system must exert an attractive influence upon all the rest. There are no earthly intellects capable of determining the courses described, and the perturbations produced, by such combinations. But the contemplation of them elevates our ideas of the wisdom and power of the great Creator, and exalts our conceptions of the profusion of beauty and variety with which immensity is filled.

OUR FIRMAMENT.

The stars, instead of being about equally scattered through space, appear to be clustered together in vast groups of many millions. These groups, or *firmaments*, as they are called, are separated from each other by measureless depths of apparently unoccupied space. The stars composing these firmaments are clustered together in forms of every conceivable variety. All the stars visible by the naked eye, and

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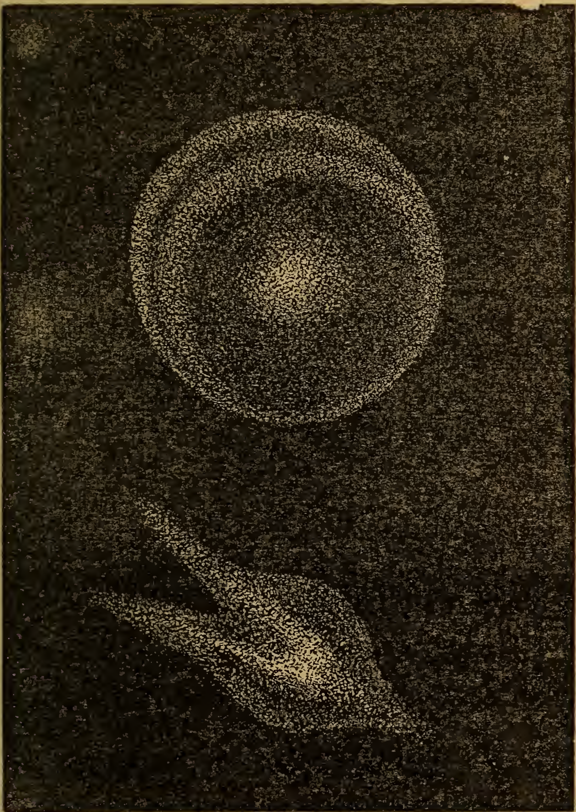
What systems are found besides binary systems? What is each star probably? Can the various movements produced by these complicated influences be easily described? Are the stars equally diffused through space? What are these groups called? How are these firmaments separated from each other? What forms do these firmaments assume? What stars belong to our firmament?

nearly all seen through telescopes of ordinary power, belong to the cluster composing our firmament. The number of suns thus congregated together, with their accompanying retinue of planetary worlds, is probably not less than three thousand millions.



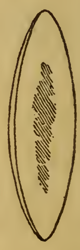
The general form assumed by the millions of stars

Of how many worlds does our firmament probably consist? What is the general form of our firmament?

which compose our firmament is that of a circle, somewhat resembling a grindstone. Nichol thus describes the general form of our firmament, as ascertained by the very laborious and accurate observations of Herschel. "You know a common grindstone? Suppose first, that the rim is split in the middle, along the line of the rim, and through about one-third of its circumference; which split, however, does not reach so far down as the centre of the grindstone; also, let the divided parts be somewhat separated towards the middle of the division, so that they run along and reenter after a temporary separation." The following plate exhibits, first a side view, and secondly an edge view, of the form of our firmament.

Side View.

Edge View.



"Suppose, secondly, that the grindstone is considerably more porous than stone is. Then, let its minute atoms represent stars, the pores, or intervals, representing the spaces between the stars; and observe what an inhabitant of a sun or world, near the centre of a cluster of such configurations, would perceive in his hea-

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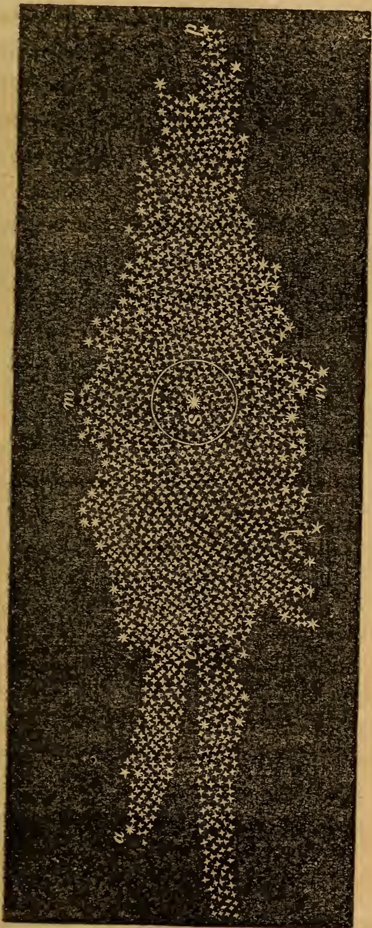
Repeat Nichol's illustration of the form of our firmament.

vens. They would be precisely similar to our own celestial vault. Towards their sides the view would



be comparatively unadorned—dark space, looming from behind the visible stars; while, in the direction

of the circumference, a countless mass of small, remote stars would, although separately unseen, illumine the sky, forming a splendid zone, divided, like our Milky Way, through part of its shadowy course." "This remarkable belt, the Milky Way," says Sir John Herschel, "when examined through powerful telescopes, is found to consist entirely of stars, scattered by millions, like glittering dust, on the black ground of the general heavens." The most remote stars in our firmament Herschel estimates to be at the distance of ten thousand billions of miles. Light, which moves with the velocity of two hundred thousand miles in a second, would require more than one thousand six hundred years to traverse this mighty interval. And yet these stars are comparatively our near neighbors; they are, as it were, the dwelling-houses of our own village.

Give Herschel's description of the Milky Way. At what distance from us are the most remote stars in our firmament? With what rapidity does light move? How long would it take light to traverse this interval?

CHAPTER VIII.

OBSERVATION.

In the preceding chapters, the object has been to present a simple view of the great facts of Astronomy, as they exist absolutely, without regard to the position of the eye which observes them, or the state of the mind which reasons upon them. The magnitudes, positions and movements of the heavenly bodies have been presented to view, as they would appear to an observer capable of moving, at will, among them, or of taking some commanding position, from which he could survey the whole in one general view, or examine each part in detail, from stations the most advantageous for the purpose.

But all this knowledge, so distinct and simple, when thus presented in a general view, has had to be very slowly gathered, step by step, by mankind. It has required more than two thousand years of time, and a vast amount of labor, to attain it. The reason is, that

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What has been the object in the preceding chapters of this work? In what point of view have the magnitudes, positions and motions of the heavenly bodies been presented? How is it said that this knowledge had to be acquired? How long has it taken to attain it?

the motions of the heavenly bodies, though very simple in themselves, are often very complicated and mysterious in appearance, as they present themselves to an observer stationed on the Earth—where, of course, all observers have been stationed, who have furnished us with any knowledge on this subject. Now it is important that the pupil should understand not only the results to which the science of Astronomy has at length arrived, but also something of the appearances which the heavenly bodies exhibit to a spectator on the Earth, from which these results have been slowly deduced—and something of the nature of the instruments and arrangements by which the investigations have been made—and also of the practical purposes to which the results of Astronomical science are applied. It is, in fact, in these points of view that Astronomy will present itself most frequently to our attention, in the course of life. For when we look upon the heavens ourselves, we see, not the simple movements which exist in reality, but the complicated and deceptive appearances, which bewildered philosophers so long. And in our intercourse with others, the aspect in which topics connected with Astronomy will present themselves in conversation, will almost always relate to these appearances, to the plans and arrangements of men for ob-

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What has been the cause of this? How many things are mentioned which it is important that the pupil should understand besides the results to which the science of Astronomy has arrived? What is the first? What is the second? In which of these points of view will a knowledge of Astronomy be the most useful? When we look upon the heavens do we perceive the simple movements which the planets are now known to make? What do we perceive? What relations of Astronomy most frequently become topics of conversation in the intercourse of life?

serving them, and to the practical advantages which they derive from the results.

If we suppose a spectator looking, for the first time, into the heavens, in a clear night, and taking a survey of the firmament, it is easy to see that his first impression would be that he was looking upon a vast concave, studded with shining points, of various degrees of brilliancy, placed entirely without order, and all in a state of repose. If, after waiting a few hours, the observer were to come and view the stars again, he would find that he had been mistaken in supposing them to be in a state of repose, for it would then be seen that the whole canopy had advanced from the east towards the west, so as to bring those stars which before were in mid-heaven towards the western horizon, while those which before were in the east would have risen higher, and those which had been near the western horizon would have passed below the horizon, out of view. Any one can observe these appearances any evening, by noticing, at an early hour, the positions of stars and groups in various parts of the sky, and then, at a later hour, looking again, when he will see that a change has taken place in their positions, not in respect to each other, but in regard to the horizon and to the meridian.

In order to make such observations as these in an intelligent and scientific manner, it is necessary for the

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What would be the appearance presenting itself to the eye of a spectator looking for the first time at the heavens? What change would he observe after the lapse of a few hours? How can these appearances be easily observed? What line is mentioned which it is important that the pupil should distinctly understand?

pupil to understand practically what the *meridian* is. Let the observer direct the finger to the point exactly over his head. This point is called the zenith. It is obvious that from this point the finger may be moved down to the horizon in any direction, north, south, east or west. The distance from the zenith down to the horizon, at any point of the compass, is obviously one quarter of a circle, or 90 degrees. The distance from that point of the horizon, whatever it may be, up to the zenith, and thence down to the opposite point of the horizon, being half a circle, or 180 degrees. Now if the finger be moved in this manner from the zenith down to that point of the horizon which is exactly *south* of the observer, it will trace the line of the meridian of that observer. All the stars which pass south of the observer will cross this meridian at right angles. The Sun crosses it every day at noon. It is to be understood that the line of the meridian continues through the northern part of the firmament in the same manner. It passes from the zenith northward through the pole, and thence to the point of the horizon which is exactly north of the position of the observer; and all the stars which are too far to the northward to pass south of the zenith, cross this part of the meridian at every revolution. It is, however, that part of the meridian which is south of the observer that is most important, as it is

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What is the zenith? What is the distance in degrees from the zenith to the horizon? How large a part of a circle is it? In which direction must the finger be moved from the zenith to the horizon to indicate the meridian? In what manner do the Sun and stars cross the meridian? Does the meridian extend beyond the zenith towards the north? Which part of the meridian is most important, that which is north or that which is south of the zenith?

this part which the Sun, the Moon, the planets, and those stars whose motions are most frequent subjects of observation, cross in their diurnal revolutions.

The reason why the meridian comes to be a line of so great importance in astronomical observations is this, viz., that it is possible to determine the time when a heavenly body crosses the meridian far more exactly than it can be determined when it passes the horizon, whether in rising or setting. This may appear strange, since the horizon is a visible reality, while the meridian is only an imaginary line, with nothing to mark its place in the heavens. But the horizon is not exactly marked, except at sea; the outline of the land being always more or less irregular. Then the horizon is more frequently obscured by mists and vapors, or by a general haziness, which conceals the celestial object from view. Then again, in looking at an object near the horizon, we look through a great extent of the Earth's atmosphere, by means of which a very deceptive refraction is produced, which does not take place when we look directly out of the atmosphere, as we do when observing an object in mid-heaven. Astronomers, therefore, always consider the revolution of a heavenly body as beginning and ending when it crosses the meridian, and not when it rises or sets. They use, in observatories, a telescope adjusted with great care to the

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What is it that makes the meridian so important a line? Why should this appear strange? How many reasons are given why the horizon is a less definite line than the meridian? What is the first reason? The second reason? The third reason? At what point do Astronomers consider the daily revolution of a heavenly body as commencing and ending? What instrument is used in observatories to determine when a heavenly body passes the meridian?

meridian of the place, with a very fine wire, like a hair, passing down across the field of view, as exactly as possible in the centre of it, and thus they can mark the moment when a star or the edge of the Sun passes this hair, far more accurately than they could the time of its rising or setting.

When the person who is making observations upon the stars is anywhere upon the equator of the Earth, the Sun and stars all appear to rise perpendicularly in the east—that is, at right angles to the horizon; and mounting the heavens in direct lines, they cross the meridian, and then descend in the west, perpendicularly, as they rose. In going from the equator towards the north pole, it is evident that these circles of motion described by the stars will decline more and more towards the south. Thus in the latitude of the United States the stars which rise exactly in the east will not rise perpendicularly and pass over the zenith, but will decline towards the south, passing round in an oblique circle, more or less oblique according as the position of the observer is more or less to the northward. At the pole of the Earth, the pole of the heavens would be exactly over the observer's head, and all the heavenly bodies would revolve in circles parallel to the horizon.

It is not possible actually to reach the pole. But

What is it in this telescope which marks the meridian? Suppose an observer of the stars is upon the Earth's equator, how will they appear to rise? What change takes place in these apparent motions as the observer goes towards the north? What will be the appearances anywhere in the United States? What would be the appearance at the pole? Is it possible actually to reach the pole?

navigators have succeeded in forcing their ships through the openings in the ice, in the summer months, to within a short distance of it; and there they find that the Sun goes round and round the horizon, nearly, though not quite, parallel to it. In the summer he is above the horizon, and in the winter, when he is farther to the southward, he is below it. So that for six months it is continual day, and for six months continual night. Or rather it is continual morning and continual evening; for as in the summer he never rises far above the horizon, and in the winter never goes far below, but only passes round and round just above or just below, the long day has always the expression and appearance of morning just after sunrise, and the long night that of evening just after sunset.

An observer in the United States would find the Sun, like the stars in the same latitude, always passing round from the east to the west in an oblique course declining to the south. The path which it describes one day is always parallel to that which it describes on another, though farther to the north or to the south, according to the season of the year. Of course, when the Sun is farthest to the north, it rises higher in the middle of the day, and passes the meridian at a higher altitude, as it is called—that is, at a greater distance from the horizon. In the winter, when the Sun is far-

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How have navigators succeeded in getting near to it? What do they find to be the apparent motions of the Sun and stars there? What effect does this have upon the day and night? What is the nature of the motion of the Sun, as seen in the United States? In which season of the year does it pass the meridian at the highest point?

ther to the south, it passes round in a lower circle, but in one which is still parallel to the other. It of course crosses the meridian at noon at a lower point, and has, at that time, a less altitude.

The term *altitude* is used to denote the distance of a body above the horizon, measured in degrees, and it is a term very frequently employed in astronomical operations. It is important that the pupil should have a clear idea of its meaning. The distance from the horizon up to the zenith is a quarter of a circle, or ninety degrees; so that a star precisely in the zenith would have an altitude of ninety degrees. A star half way between the horizon and the zenith would have an altitude of forty-five degrees. One-third of this last distance would, of course, be represented by fifteen degrees. It would be a very useful exercise for the pupil, with these *data* in mind, to estimate the altitudes of various stars as seen in the heavens, both with a view of fixing permanently in the mind the precise import of the term, and of gaining some practical idea of the distances which would be thus compared with each other.

It is important not to confound the word *altitude* with *latitude*. The latter is derived from a Latin word

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At which season has it the least altitude when crossing the meridian? What is altitude? What is the distance in degrees from the horizon to the zenith? What then would be the altitude of a star in the zenith? What would be the altitude of a star half way between the zenith and the horizon? What exercise is recommended as useful to the pupil in this connexion? Point to the horizon. Point to the zenith. Point to an altitude of about forty-five degrees. Point to an altitude of about forty degrees. Of about twenty degrees.

which means *side*, and it denotes the distance which a place upon the Earth's surface is, upon one side or the other of the Earth, reckoning from the equator. The other term is derived from a Latin word meaning *high*, and denotes the elevation of an object in degrees, measured from the horizon. Thus we say that in high *latitudes*, meaning far to the north, the Sun never attains a great *altitude*, but passes around the horizon at a short distance above or below it.

On observing the heavenly bodies in different latitudes, we find that they rise, ascend and cross the meridian, and then descend and set, in circles more or less oblique according to our distance from the equator —nearly all of them, however, preserving the same relative position. That is, if a group or cluster of stars rise together, presenting to the eye a certain configuration, they pass on together, crossing the meridian and descending in the west, preserving all the time the same relative position in respect to each other. The next evening the same group rises again, presenting precisely the same configuration as before, and in the same position in respect to surrounding groups. Thus the stars have continued their revolutions, without changing their places in respect to each other, so far as the human eye can perceive, during all the centuries which have elapsed since they were first observed.

This fixedness in respect to each other does not, however, apply to quite all the stars. As has already

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What is the distinction between the *altitude* and *latitude*? What is meant by the stars preserving the same relative position? What appearances does any observed group of stars present on successive evenings? Are all the stars thus fixed in relation to each other?

been explained, there are a few which wander about among the rest. When these wandering stars were first observed, their strange and mysterious motions were the subject of continual wonder. Sometimes they would move backwards and sometimes forwards—sometimes fast and sometimes slow. The motions of these bodies are however now fully explained by the Copernican system; their wanderings being all accounted for by the combined effect of their own motion and ours, as all revolve around the common centre, the Sun.

To make a map of the stars, and to mark upon it the wanderings of a planet, it is only necessary to contrive some instrument for measuring their distances from each other, and then marking their places upon a sheet of paper at these distances. Ferguson, a celebrated Astronomer, when a boy, contrived a very simple instrument for this purpose. It consisted simply of a thread with a little knot near one end, and a small bead upon it. This bead could be slipped along the thread, and would remain at any part where it was placed. By holding this thread out at arm's length, the apparent distance of two stars could be measured, by bringing the little knot to correspond with one of the stars and then slipping the bead till it corresponded with the position of the other. In doing this, the string was to be held at arm's length against the sky. When the

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What appearance do the wandering stars present in respect to their motions? Are all these wanderings now explained? What is necessary in order to make a map of any particular portion of the heavens? What plan did Ferguson adopt when a boy? How was this apparatus used? How was the string to be held?

bead was thus adjusted upon the string so as to correspond with the distance of some star from another star, the string was laid down upon the sheet of paper and two dots made upon the paper, corresponding with the knot and with the bead. Thus the apparent places of the two stars were indicated upon the paper.

To find and mark the position of a third star, it was necessary to measure its distance from both the others, in order to determine its position in relation to both. This, with a little practice, can be easily done; and young Ferguson was accustomed to make very neat and pretty maps of the constellations by measuring the sidereal distances in this way. The correctness of the result, in using such an apparatus as this, will depend mainly upon the observer's extending his arms equally at each successive measurement, so as to have the thread always at the same distance from the eye. For when the thread is held near the eye, any given length will cover a much larger distance in the sky than when it is held out far from it.

Altitudes, as well as other distances, may be measured by such a thread as this. If the observer takes the knot between the finger and thumb of the right hand, and holds it over his head, and then slips the bead down until it is opposite the horizon, keeping the arms extended, so as to have the thread as far as

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How were the distances thus ascertained transferred to paper? How many measurements are necessary in order to ascertain the position of a third star, after two have been laid down upon the map? What does the correctness of the result in these measurements mainly depend upon? Why? Can altitudes as well as other distances be measured by this apparatus? How can the bead be adjusted so as to represent a distance of ninety degrees?

possible from the eye, the length included between the knot and the bead will correspond with the distance of ninety degrees. If now the thread be doubled upon itself, to find the middle of it, and the bead be slipped to the middle point thus found, the distance then from the bead to the knot will represent forty-five degrees; and by this measure the observer can easily ascertain what stars are about forty-five degrees from the horizon. In the same manner the thread might be subdivided farther, and the points marked by little colored threads, introduced with a needle, so as to make it answer the purpose of measuring approximately a great number of altitudes and distances. Of course, the results would be very far from being accurate, as this method of measurement is liable to many sources of error. It is sufficiently accurate, however, for the purpose here intended, viz.: to give the pupils who might use it a correct idea of the *nature* of the quantities thus measured, and to familiarize them with the terms used in speaking of them, and also to enable them, when in their reading or in conversation they hear distances in degrees and minutes mentioned, to form some practical conception of the import of such expressions.

How to represent a distance of forty-five degrees? Can accurate measurements be made by this apparatus? What advantages, then, will result from the use of it?

CHAPTER IX.

INSTRUMENTS AND OBSERVATORIES.

SUCH an apparatus as was described in the last chapter is of no service for obtaining *correct* results or measurements. It will only answer to aid the pupil in forming clear conceptions of the *nature* of the operations and measurements themselves.

For the practical purposes of Astronomy, it is necessary that instruments of the greatest exactness and nicety of construction should be provided. The place in which they are used must also be suitable. The instruments must rest upon a solid foundation, where they will not be subject to any tremor or jar, and must be placed in buildings where they will be protected from injury, while yet openings are provided which will allow of examining every part of the sky. An establishment fitted up thus for astronomical observations is called an *observatory*. Some observatories are public, being built, furnished and sustained at the expense of governments. Some are private,

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What is the only advantage to be derived from such an apparatus as was described in the last chapter? What is said to be essential for the practical purposes of Astronomy in respect to instruments? In respect to the place where they are used? What is such a place called? What two classes of observatories are mentioned?

being the property of gentlemen interested in Astronomy as a pleasurable pursuit.

The observatory most known in the English world is the Royal Observatory at Greenwich. Greenwich is a town a few miles below London, on the Thames. The observatory is situated on rising ground, back from the river, and is celebrated for the long series of exact observations which have been made there, and for the eminent Astronomers who have been connected with it. There are public observatories also in many other parts of Europe and in the United States, some connected with governments, and others with literary institutions. At these observatories a great variety of instruments are set up, for making the different observations required.

The telescope is the great instrument of Astronomy, and it is constructed on the following principles.

When we look at an object with the naked eye, it is only that small portion of the light coming from it which can enter at the pupil, which furnishes us with the means of vision. Now, the essential object of the telescope is to gather together a larger beam of rays, and then, by means of glass *lenses*, or mirrors, bring them into the eye in the proper condition for producing distinct vision. There is, therefore, in a telescope always one large glass, or large mirror, to

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What is the most celebrated observatory in the English world? How is it situated? What is said of other observatories? What is the great instrument of Astronomy? When we look at an object with the naked eye, what portion of its light only is available for producing vision? In what manner does the telescope increase this supply?

collect the rays. There is also, besides this, a series of smaller glasses, to change the directions of the rays after they are gathered, so as to cause them to enter the eye in a proper manner to produce a distinct image, or else to vary the nature of the image, according to the wish of the Astronomer. For example, one set of small glasses will make the image larger, but more faint; another will make it smaller, and more bright;—both sets depending entirely for what they can do on the quantity of light gathered for them by the large lens, or large mirror, which first receives the rays.

Those telescopes which gather light from the object to be viewed, by means of a *mirror*, are called *reflecting* telescopes, or *reflectors*. In the smaller reflecting telescopes in use, the mirror for gathering the rays of light is from a few inches to a foot in diameter. This mirror is commonly called a *speculum*. The celebrated great telescope of Herschel had a speculum four feet in diameter. The tube of this telescope was forty feet long, and the observer sat in a little gallery attached to the upper end of it, and looked down into the tube, the great reflector being at the lower end. To support so large a tube, and to furnish the means of moving it, so as to direct it to any part of the heavens, required a very complicated and heavy frame-work, and the

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What other glasses, or mirrors, are required? What objects do these secondary glasses or mirrors accomplish? What are those telescopes called which gather a supply of light by a mirror? What name is given to this mirror? How large was the speculum in Herschel's large telescope? How long was the tube? What was the position of the observer in using the instrument? Where was the speculum placed? How was the instrument supported and moved?

whole was necessarily placed in the open air. It remained for some years, when at length the frame decayed, and it was taken down.

Since this time the Earl of Rosse, an English nobleman, has constructed a reflector much larger than Herschel's. The speculum is six feet in diameter, and the tube is fifty-six feet long. It is placed in the open air, with high walls on three sides of it, and it is supported in its proper position by chains. The cost of this instrument has been about fifty thousand dollars.

From the nature of reflection it is obvious that in all telescopes constructed on this principle, the speculum must be placed in the end of the instrument farthest from the object, and unless there is a second reflector the observer must turn his back to the object, and look into the telescope from the outer end. Unless the telescope is very large, a considerable portion of the light would be intercepted by this arrangement. In small reflectors there is, accordingly, a small mirror placed near where the eye of the observer would come, on the preceding plan, and the rays are reflected by this mirror back through a hole, made for the purpose, in the centre of the great speculum. A little tube, containing the proper eye-glasses, is screwed to this orifice on the back side, and the observer then views the object directly, as in ordinary glasses for land objects.

What became of the instrument at last? How large is the speculum of Lord Rosse's telescope? How long is the tube? How is it mounted? What must always be the position of the speculum in the telescope? Where would the eye of the observer naturally come? By what contrivance is the place for the eye of the observer carried to the other end of the instrument?

The great difficulty in the manufacture of reflecting telescopes is in making the great speculum. It must be of metal, for a glass mirror always gives a double image, one reflection taking place from the front surface, and one from the back. This effect is not very striking in a parlor mirror, reflecting only the objects in the room,—though any one who examines the image of any small bright object in such a glass, will perceive that the outlines are double, and a telescope, constructed *with such a mirror*, would give a distinct double image of every star which it should be brought to bear upon. The speculum must be therefore metallic, so as to have but one reflecting surface. The composition must be such as to bear a very high polish, and yet not be too hard, so as to make the labor of grinding and polishing it too excessive. It must also be of such a nature as not to tarnish by exposure to the atmosphere, nor crack from the effect of changes of temperature. The mechanical difficulties of casting and managing so large a mass as that of some reflectors which have been made, are very considerable. Herschel's great reflector, four feet in diameter, weighed about two tons. That of the Rosse telescope weighs four tons. To prevent such castings from cracking it is necessary to cool them very slowly. This process is called *annealing*. The great mirror of

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What is the great difficulty in the manufacture of reflecting telescopes? Why will not glass reflectors answer? How may the double reflection of a glass mirror be made evident? What effect would a glass reflector have upon the appearance of a star? What are some of the properties which the metal used must have? How heavy was Herschel's great reflector? How heavy is Lord Rosse's?

the Rosse telescope, as soon as it was cast, and while yet red-hot, was rolled, upon a railway prepared for the purpose, into a heated oven, where it was left *sixteen weeks* to anneal.

There is another great objection to the use of a reflector to collect the light from an object for telescopic purposes, and that is that only a part of the light so collected is reflected—the remainder being dissipated or absorbed at the reflecting surface. For this and other reasons, a glass, of the form of those used under the name of sun-glasses, provided it be perfect, is better for the purpose of collecting rays of light, than a reflector of the same size. Such glasses are called *lenses*. A lens which is thicker in the middle than at the edges, so as to have its surfaces convex, is called a convex lens. This is the case with the glasses of such spectacles as aged persons wear. The effect of such a lens is to draw the rays of light together—that is, the rays *converge* after passing through it, and meet in a point called the *focus*. If the lens is thinner in the middle than at the sides, so as to make the surfaces *concave*, it is called a concave lens. This is the kind of lens used in the spectacles which near-sighted persons wear. The effect of this kind of lens

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How long was Lord Rosse's speculum in cooling? Why was it necessary to cool it so slowly? What other objection is there to the use of a reflecting surface as a means of collecting light? What other means is there of accomplishing the purpose? What is the name given to a lens which is thicker in the middle than at the sides? What is the effect of such a lens upon the rays of light? What is the point called to which such rays converge? What is the name of a lens thinner in the middle than at the edges? What is its effect upon the rays of light?

is to *disperse* or scatter the rays which pass through it. The different effects produced by these different kinds of lenses may be made manifest by holding two pairs of spectacles, one of each kind, to the sun, and receiving the rays, after they pass through the glasses, upon a sheet of paper, as a screen. By holding the paper, at first, very near the glass, and then gradually withdrawing it, the different effects of the two glasses will be very apparent, the bright spot upon the paper expanding, in the one case, as the rays scatter—and gradually contracting, in the other, until the rays meet in the focus. To make the experiment quite satisfactory, a sheet of paper with a hole in it as large as the glass, should be placed outside the glass, in each case, so as to prevent any rays falling upon the screen except such as come through the glass. The change thus produced in the direction of rays by passing through a lens, is called *refraction*.

The principal lens used in telescopes is a convex lens, and is placed, not like the reflector at the inner end of the instrument, but at the outer end, so that the object is seen through it. Telescopes constructed in this way, with a great *lens* instead of a great *reflector*, are called *refracting* telescopes, or refractors,—as the others are called *reflecting* telescopes or reflectors. The large lens employed to collect the rays of light, in a refracting telescope, is called the *object-glass*, as it is placed at that end of the telescope which is towards the

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How may these opposite effects be made evident? What is this changing of the direction of the rays of light in passing through a lens called? What name is given to a telescope constructed on this principle? What is the great lens in a refracting telescope called?

object. The glass nearest the other end of the instrument, being the one which comes next the eye, is called the *eye-glass*.

The great work in the manufacture of a refracting telescope, is to form this object-glass; it being found extremely difficult to procure glass of a perfectly uniform texture and of sufficient size, and then to grind it to its true form; for any inequality, either in the nature of the glass itself or in its form, will prevent the rays converging with that regularity essential to the forming of a distinct and well-defined image.

In former times there was a great difficulty in constructing large refracting telescopes, from the circumstance that the images produced by light coming through such lenses as have been described, are always surrounded with a little colored fringe, which fringe became very conspicuous when the instrument was large. A remedy for this was at length discovered. It consisted in having the lens made of two pieces of glass, of different kinds, instead of one. These pieces were nicely fitted together, the joining surface of one being concave, and that of the other convex. The effect of the different kinds of glass was such, that the coloring influence of one was neutralized by the other, and a colorless image was formed. Such lenses are called *achromatic*, which signifies without color. Since this discovery, it has been found better to make most tele-

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What is the glass next the eye called? What is it that requires the most delicate work in the manufacture of a refractor? What are the two sources of difficulty? What objection formerly existed to the use of such instruments? How has this evil been obviated? What name is given to those instruments which are constructed in this way? On what account is a lens preferable to a mirror?

scopes in this way, as a much larger portion of the light is lost when it is reflected from a mirror than when it is refracted by a lens. On this acount it is not necessary to make lenses used as object-glasses nearly as large as the reflectors used in the reflecting telescopes. Very few reflectors have ever been made with a lens more than ten or fifteen inches in diameter.

It requires some experience and skill to *use* a telescope as well as make one, as there are many difficulties to be guarded against or surmounted. In the first place, the telescope must have a very firm and stable footing, for it magnifies its own tremors as well as the objects which it aids us to view. Tremors which are entirely insensible to our unassisted observation, become very great in their influence upon such an instrument. The vibrations produced by the wind upon the walls of an ordinary building, and the jars occasioned by the passing of carriages in a street, will be sufficient to make the stars dance in the field of view of a telescope so as to make it impossible to get any distinct view of them. For this reason, a high position is not favorable for astronomical observations, excepting for such observations as are made with the naked eye, an instrument requiring a more solid support than can generally be obtained upon a roof or a cupola. In most observatories, in fact, there is a solid mass of masonry built from the ground, upon which, as a foundation,

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What is the size of the largest lenses which have been constructed? In using a telescope, what is necessary in regard to its position? Why is it necessary to give such an instrument a very stable position? What kinds of jars and tremors are ordinary buildings subject to, which would interfere with telescopic observations?

the instruments rest. The floor upon which the observer and his attendants walk, is made independent of this, so that the tremors occasioned by their movements may not be communicated to the instruments.

A second difficulty which an inexperienced observer finds in his way, in first using a telescope, is in adjusting it to his eye. The tube which contains the small glasses next the eye, has to be drawn out a little, sometimes more and sometimes less, according to the distance of the object which is to be observed, and also according to the condition and structure of the observer's eye. This last is the most difficult; for if the instrument had only to be adjusted to the object, one person who was more skillful and experienced, could make the adjustment for another who was less so. But when it is properly adjusted to the object to be viewed, so that one individual can see it distinctly, if another, whose eye is a little different, attempts the observation, the image will be indistinct, and he will have to move the tube in or out a little, by means of a screw, before he can see plainly. This requires a care and a precision which many persons fail to exercise at their first attempts to use such an instrument; and after looking through it for a time they either perceive that they do not get a distinct view, and after repeated efforts get discouraged and abandon the attempt, or else, after gazing a moment at the dim or confused images which they per-

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What difficulty is there in the adjustment of the instrument? Can one person adjust it for another? Why not? Are persons always successful when they first attempt to look through a telescope? In what two ways does the experiment sometimes result?

ceive, go away, imagining that that is all that is to be seen.

The state of the atmosphere is also of great importance to be attended to in astronomical observation. Often, when the weather is not cloudy, there is a dimness in the air, and oftener still a waving motion of currents which disturbs the vision. Herschel thought that there were not more than one hundred *hours* in a year in England really favorable for the observation of celestial phenomena by telescopic instruments.

There is another difficulty which often surprises those who, for the first time, attempt observations with the telescope, and that is the difficulty of *finding* the object, or rather of bringing it into the field of view of the telescope: for, it must be observed that the instrument magnifies spaces as well as objects of vision, and the region of the heavens brought into view by it, in any one position, is only a very small space, greatly expanded by the power of the instrument. If the observer wishes to look at a particular star, and points the instrument towards it, judging of its direction only by the eye, the probability is that it will deviate far enough to one side or the other, to throw the star out of the field of view. There is a very simple contrivance which obviates this difficulty. It consists in attaching a small telescope to the side of the larger

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What is said of the state of the atmosphere in such observations? Is it sufficient that it be not cloudy? What are the other causes of obscuration? How much time did Herschel think could be calculated upon, on the average, in England, as really favorable to such observations, in a year? What is the difficulty in respect to *finding* the object? What is the cause of this difficulty? In what way is it remedied?

one. This small telescope is called a *finder*, and as it magnifies but little, a star or other object is easily found in it. Across the field of view of this small telescope are two cross hairs, and when the whole instrument is adjusted to such a position as to bring the star at the intersection of these cross hairs, in the small telescope, it will be sure to come somewhere within the field of view of the larger one.

It follows, also, from the nature of the magnifying powers of a telescope, that it must magnify *motion*, as well as magnitudes and space, and accordingly the apparent motion of a star is much greater across the field of view of a telescope, than when seen by the naked eye. This requires a very frequent movement of the instrument to follow it and keep it in view.

The most striking and interesting objects to be viewed by means of large telescopes, are the planet Venus, which appears like the moon in some of its phases; Mars; Jupiter, with his belts and his moons; the rings and the moons of Saturn; the Earth's moon, especially when the Sun shines upon its surface in such a manner as to cause its elevations and depressions to cast strong shadows; the spots on the Sun; comets; and lastly, some nebulæ and clusters of distant stars.

Besides these large telescopes, intended mainly to *view* objects in the heavens, there are others employed by astronomers, which are mounted in various ways, with arcs very precisely divided into degrees, minutes

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What is said in regard to the motion of a star across the field of view of a telescope? What are some of the most interesting objects to be viewed by a telescope? What is a transit instrument? How is it mounted?

and seconds, for measuring accurately various celestial magnitudes and distances. Sometimes such a telescope is mounted in such a way as to point always to the meridian, but poised in such a manner that it may be elevated or depressed to any degree of altitude. This is called a *transit* instrument. Of course the mounting of a transit instrument does not allow of its being directed to the eastern or western region of the sky. It is confined to the meridian, and it has a hair passing down across the field of view which marks the precise meridian of the place; and thus the moment when a star crosses this hair will be the precise moment of its crossing the meridian. Observations of the time when bodies thus pass the meridian are among the most important of all astronomical observations. A great many problems, measurements and investigations depend upon them. The transit instruments, therefore, in all observatories, are adjusted with great care. In the great observatory at Greenwich there is a particular room called the transit room, where there is a large telescope placed firmly upon a stone foundation, and adjusted with great precision, so as to move only in the meridian. The object-end may be raised or depressed to any angle, but it cannot move to the right or left; so that whatever its position may be, the cross hair passing down through the centre of its field of view, marks the meridian in that part of the heavens. Behind the instrument is a chair for the observer, with a back which may be inclined at any

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How is the precise place of the meridian marked in the field of view? What kind of motion does its mounting allow of? How is the transit instrument arranged at Greenwich?

angle, to give him a good position for looking through the telescope, at any point of elevation.

It is obvious that a transit instrument can only mark time. It cannot measure distances directly, nor examine appearances or phenomena to advantage. For it cannot move from one part of the heavens to another, except simply up and down in the meridian; so that it cannot directly compare the position of one star with another, nor follow a planet or a nebula, so as to keep it in the field of view, and examine its appearance at leisure. It is only employed to mark the precise time when the heavenly bodies, one after another, pass the meridian of the place where the observation is made. Certain distances can be deduced from the result of transit observations, it is true; for by comparing the time which intervenes between the transit of one body and another, certain relations of their distance from each other can be ascertained. The result always is, however, in the first instance, the marking of time; and for this purpose, a clock of the most perfect construction possible must accompany a transit instrument. It requires two observers to make the observations—one to look through the telescope at the star, and to give a signal at the precise instant when it disappears behind the cross hair, and the other to note the time by the clock. The necessity for great accuracy in these results arises partly from the fact, that the tables by means of which

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Is a transit telescope fitted to measure distances directly, or to survey appearances in the heavens? Why not? What is the sole and simple object which it aims at? How many observers are necessary? What other instrument is required? Why is it necessary that the observations should be made with so much accuracy?

the place of a ship at sea is determined are all constructed by means of these and similar observations; and an error of a part of a second, in the time of a transit, might cause an error of many miles in the calculations of all ship masters who should depend upon the tables affected by such an error.

Besides telescopes mounted as transit instruments, there are others so mounted as to allow of free motion in any direction, with various arcs very nicely graduated, by which the exact extent of every motion given them may be ascertained. Some of these have clock-work attached to them, which causes them to move in such a manner as to keep pace exactly with a star or other heavenly body brought into view. In this case the observer may sit quietly for hours, if he choose, and survey any appearance which attracts his attention; the machinery keeping the object of his observation always before him. The motion of such a telescope must of course be always parallel to the equator, as the heavenly bodies generally move in circles of that description. Such an instrument is called an *equatorial* instrument, or simply an *equatorial*.

Suppose it is required to mount a telescope so as to follow a star and keep it for some time in view, what motion must it have? What is a telescope so mounted called? What machinery is sometimes attached to it?

CHAPTER X.

PRACTICAL RESULTS.

Perhaps the greatest practical benefit which mankind derive from the science of Astronomy, is the aid which it renders them in conducting ships over the ocean. A ship, once beyond sight of land, has to rely almost entirely upon the heavenly bodies for its guidance. Of course it becomes necessary that the motions and positions of these bodies should be known with great accuracy. These motions and positions are ascertained, in the first instance, by such observations on land as were described in the last chapter. The results are recorded in tables, which navigators take with them to sea; and then they ascertain their position by comparing the results of their observations, as made from the decks of their ships, with the records made in the books of the results of the Astronomers' observations on the land.

What is the greatest practical benefit which mankind derive from the science of Astronomy? Upon what is a ship at sea obliged to rely as a means of knowing her position? What then becomes necessary in respect to the motions and positions of the heavenly bodies? How is this effected?

The instruments on which ship-masters mainly rely at sea are two: first, an instrument to measure the distance of a heavenly body from the horizon, or of one heavenly body from another; and secondly, an instrument to keep the time of London, or of some other known place, wherever they go. The most common instrument for the former purpose is one called a quadrant. It is so called on account of its measuring a distance of ninety degrees, which is the quarter of a circle. The instrument is small, being about a foot in length. It has to be held in the hands while making the observation; for, on account of the motion of the ship, no instrument resting upon the deck could possibly be used. The quadrant is very complicated in its construction, and requires much skill and practice to use it to advantage. The principle, however, on which it is constructed, is simple. It is designed to measure the distance between two objects, as, for example, between the Sun and the horizon; and it is so contrived that one of the objects is seen directly, through a plain glass, and the other reflected through a small mirror. The mirror is movable, and may be turned until the object seen directly, and the one seen in reflection, shall come precisely together at the junction between the silvered part and

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How many are the instruments principally required by ship-masters? What are the objects of these two species of instruments? What is the name of the instrument most commonly used for measuring distances? Why is it called a quadrant? How large is such a quadrant? Why could not a stationary quadrant be used at sea? Is it easy to understand and use the quadrant? Describe the principle on which it is constructed.

the transparent part of a small plate of glass, where both can be seen. Now the degree to which the little mirror has to be turned to effect this junction, shows how far distant the two objects are from one another. The mirror is attached to an index which moves upon a brass or silver arc, on which the degrees and minutes are accurately marked, and thus the result of the measurement is ascertained.

The sextant is an instrument similar in principle to the quadrant; but it measures a greater distance, is usually made with greater care, and is more expensive. It is used for the larger ships and the more distant voyages.

Every day, when it begins to draw near to twelve o'clock, the officers of every ship at sea come upon deck, with their quadrants or sextants in their hands, to take the Sun's altitude at noon, for the purpose of ascertaining the ship's latitude. The latitude of a place is its distance from the equator, to the north or to the south. Now it is very obvious that in this hemisphere the farther south the observer is, the higher the Sun will rise at noon, when he passes the meridian. It is true that the Sun changes his position every day, so as to pass the meridian at a different altitude, as seen from the same place; but then these changes have all been calculated beforehand, by Astronomers, upon the land, and tables have been constructed show-

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What is a sextant, and how does it differ from a quadrant? At what time of the day do the officers come on deck to take their observation? What measurement is it that they wish to take? What effect does the position of the observer on the Earth, in respect to latitude, have in respect to the *altitude of the Sun* at noon?

ing how far the Sun moves to the north or south of the equator for every day, hour, minute and second of the year; so that the navigator has the means of knowing, from his books, at what altitude the Sun ought to cross the meridian for every mile of latitude on the Earth's surface, from the equator to the pole, and for every day in the year. He has, therefore, on any given day, only to ascertain, with his quadrant, at what elevation the Sun does pass the meridian where his ship is, in order to find from his books how far north of the equator the ship must be.

When it is cloudy this observation cannot be made; and sometimes several days elapse, during which the mariner cannot "get an observation," as it is called. At such a time, the only means of knowing his position from day to day is by a reckoning of the distance and direction of the sailing, since the time when the last observation was made.

But when the altitude of the Sun at noon can be obtained, it furnishes a very ready mode of obtaining the ship's place in respect to latitude; and so exact are the quadrants in their graduations, and so accurate are the tables of the Sun's position, contained in the books of navigation, that the place of a ship, in respect to its distance north or south of the equator, can be ascertained with great accuracy—often within a mile.

The place of a ship in *longitude* is far more difficult

How does the navigator find the latitude of the place from knowing the Sun's altitude at noon? What is done when the sky is cloudy? With what degree of accuracy can the ship's place be found in latitude when a good observation is obtained? Is it equally easy to find a ship's place in *longitude*?

to be determined from observations of the heavenly bodies, though the principle on which it is obtained is equally easy to be understood. It is simply to compare the time of day at the place of observation with the time of day at London, at the same instant. This is on the principle that the difference in the longitude of any two places always corresponds exactly with the difference in the time. The reason of this is, that as the Earth revolves on its axis by a perfectly equable motion, it brings the successive portions of its surface to the Sun at periods exactly proportioned to their distance from each other in longitude. Of course, the difference *in time* in which two places come to the Sun is always a measure of their difference of longitude.

This may be made very evident by considering a particular example. The Fejee Islands, in the Pacific Ocean, are just about half round the world, measuring from London. Of course, when it is noon at London it is midnight at the Fejee Islands. Now, suppose a person at these islands, not knowing in what part of the world he was, could in some way learn at midnight there, that it was, at that time, exactly *noon* at London; he could easily infer that he must be precisely on the opposite side of the Earth. In other words, by knowing that there was twelve hours' difference in the time when the Sun would be on the meri-

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What is the principle on which the distance between two places, in longitude, is found? Why is it that the difference in time of any two places always corresponds to the difference in longitude? What islands are mentioned which are half way round the world from London? This being the position of those islands, what time will it be there when it is noon at London?

dian of the two places, he would be sure that there was 180 degrees of difference in their longitudes.

In the same manner, if an observer at Calcutta were to learn, at noon there, that it was at that instant only six o'clock in the morning at London, which would be very nearly the fact, he would perceive that the distance of the two places in longitude was such that it would require six hours for the Sun to pass, in his apparent motion, from the meridian of Calcutta to that of London. Now, as it requires twenty-four hours for a complete revolution of the Sun, six hours would represent quarter of a revolution, and consequently Calcutta must be 90 degrees east of London. Since six hours correspond with a distance of 90 degrees, two hours would represent 30 degrees, and one hour 15 degrees. Hence, difference of time may be always converted into difference of longitude, at the rate of one hour to 15 degrees.

Of course it becomes necessary, in order to ascertain how far a place is, in longitude, from London, to know the precise time at the place in question, and also the time at London at the same instant. The time at the ship is easily obtained every day, by observation of the Sun. The London time is carried all over the world, by means of very exact time-keepers, called *chronometers*, which are set in London, or at some other port, and

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Suppose it were to be ascertained, at noon, in Calcutta, that it was, at that moment, six o'clock at London, what might be inferred as to the distance of the two places in longitude? How many degrees of longitude are measured by one hour of time? What is it consequently necessary to know, at any place, besides the time at that place, in order to know its distance, in longitude, from London? How is the London time known at sea?

not altered during the voyage. The observatory at Greenwich is on a hill back from the Thames, a little below the city, at a place where it can be seen from many ships in the river; and in order that all the chronometers may take the precise time, before the commencement of the voyage, a signal is given from the observatory to mark the moment when it is twelve o'clock precisely, each day. This signal consists of a black ball upon a pole, which rises from the top of one of the buildings. The pole passes through the ball, and is so contrived that the ball can slide up and down the pole for a few feet. The ball rests usually at the lower end of the portion of the pole over which it slides, where, however, it is plainly visible. Five minutes before twelve it slowly rises half way up. This is to call the attention of all the ship-masters who wish to take the time. At a few seconds before twelve it rises the rest of the way, and at twelve precisely it falls back to its original position. The chronometers thus set, the navigators can carry the London time with them wherever they go; and by comparing it with the time of the place they happen to be in, every day, at noon, they can always ascertain their longitude. If their time is *before* the London time, they know they have gone eastward. If it is *one hour* earlier, they must have gone fifteen degrees to the eastward. If their time is two hours later than the Lon-

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Describe the arrangement by which the true time is given to the ships in the port of London. Suppose the time at the ship is *before* the London time, is the ship to the eastward or westward of London? Suppose a ship finds her time to be two hours later than London time, which way and how far is she from London in longitude?

don time, they must have gone thirty degrees to the westward, and the same principle applies in all other cases.

The chronometers carried to sea are made with the utmost care, as the safety of the ship often depends upon their accuracy. They are in the form of large watches, and they are set in a box, in which they are poised upon two pair of pivots, at right angles to each other, so as to allow of easy motion in every direction, that they may accommodate themselves to the rocking of the ship. They are so exact that they sometimes vary from their rate but very few seconds in going the longest voyages, and visiting every quarter of the globe.

There are other modes by which the navigator may obtain the London time at sea, besides taking it along with him in his ship by means of a chronometer. The principle on which these other methods are founded is this: every change which takes place in the situation of the heavenly bodies is known beforehand by Astronomers, having been carefully calculated from the known laws of the celestial motions. Now, in respect to all such changes as can be observed by ship-masters at sea, the times when they will occur, as seen at London, are accurately noted in tables which the navigator takes with him; and by observing those changes at sea, he can learn from his tables what time it is at London when they occur.

How are the chronometers which are used at sea made and mounted? Are there any other modes by which the London time can be obtained at sea, besides by means of a chronometer? Describe the method.

The phenomena most in use for this purpose, are those connected with the motions of the Sun and Moon. The Moon's apparent motion is slower than that of the Sun, so that she rises about an hour later each day than the day before. When she rises very nearly at the same time with the Sun, she cannot be seen; but after a few days, she gets to such a distance that both are visible, each in its own quarter of the heavens, as long as both remain above the horizon. Now, on account of the difference in the rate of motion of these two bodies, the distance between them is enlarging or diminishing all the time, and the difference is perceptible, by means of good instruments, for every second. Of course the navigator can get the exact distance between the Sun and Moon at any given moment. Say when it is ten o'clock in the morning by *his* time, he then looks into his books to find at what time, *at London*, the Moon was to have been at precisely that distance from the Sun; and if he finds that it was at eleven o'clock, he infers that he must be fifteen degrees to the westward of London. This measuring the distance from the Moon to the Sun is called a *lunar* observation.

There are other celestial phenomena which are made use of for this purpose, besides the distance of the Sun and Moon; but the principle is the same in all cases.

The relation between longitude and time, by which a difference in the one is always attended by a differ-

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What observation is made for this purpose? What is this observation called? What peculiar phenomenon, in respect to the length of the day at sea, results from this relation between longitude and time?

ence in the other, gives rise to a peculiar phenomenon in respect to the length of the day at sea, which is very familiar to all navigators, but is sometimes difficult to be understood by those who are accustomed to a fixed residence on land. The phenomenon is, that the length of the day—that is, the time from one noon to another—is quite different in different circumstances. The day at sea is sometimes considerably less than twenty-four hours long, and sometimes considerably more. This depends on the circumstances of the motion of the ship. If she is going to the eastward, the day is shortened; if she is going to the westward, it is lengthened. The manner in which this effect takes place may be thus explained:

Suppose a ship to be becalmed at sea, and to be, consequently, at rest. It is obvious that it will be just twenty-four hours from the time that the Sun leaves her meridian, until the time that he returns to it again; in other words, that the length of the day on board that ship will be just twenty-four hours. But now, if we suppose that the ship, instead of remaining at rest, were driven *five degrees* to the eastward by a gale of wind, she would have gone so far on the way to *meet the Sun* in his rising the next day. It is plain that, by this change of five degrees in her place, the Sun has five degrees *less* than his whole

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Is the day at sea always twenty-four hours in length? How does it vary from this standard? On what does the variation depend? Suppose a ship remains stationary in a calm, what will be the length of her day? Suppose she moves five degrees to the eastward, will she lengthen or shorten her day?

circuit to perform before he comes to her meridian on the second day. Now, as fifteen degrees correspond to one hour, five degrees will correspond to one-third of that time, or twenty minutes. So that the day, in this case, will be twenty minutes shorter than twenty-four hours. In other words, it will really be twelve o'clock when, by all the watches on board which were set right the day before, it is only *twenty minutes* of twelve.

In the same manner, suppose the ship to go five degrees to the westward, between one noon and another—say between Monday and Tuesday noon. In this case, the Sun will have *more* than a whole revolution to make, before he can bring to the ship her second noon. He will have first to complete one revolution, which will bring him over the place where the ship was on Monday noon. But she will be no longer there. She will have moved five degrees farther to the west. Of course, the Sun will have this five degrees to traverse before he can again come into the meridian of the ship. This will take twenty minutes, and this will make the day twenty-four hours and twenty minutes long; so that it will not be really twelve o'clock until it is *twenty minutes past twelve* by all the watches on board.

It follows from this, that the days of all ships sailing eastward are a little less than twenty-four hours long, and those of ships sailing westward are a little

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How much will she shorten it? Suppose the ship to be going westward, will she lengthen or shorten her day? How will this take place? How much will she shorten it by going five degrees? Are the days of ships going eastward lengthened or shortened? How is it in going to the westward?

more. The officers, therefore, of a ship going eastward must be on deck by half-past eleven every day, with their quadrants, so as to be sure to get the altitude of the Sun when on the meridian; while those who are going westward may wait until their watches indicate twelve.

Astronomy thus contributes very largely to the comfort and happiness of mankind, by guiding the ships in which the products of different climes are transported to and fro over a boundless waste of waters, which, without her aid, would be almost utterly impassable. The accuracy of the tables which she has constructed is the result of long series of observations and of calculations, involving an amount of labor of which the mass of mankind have little conception. If these tables and the other records of the celestial motions were to be destroyed, it would require many years of time, and an enormous expenditure of scientific labor and research, to open safe ways again over the waters of the ocean.

The study of Astronomy has not only proved of vast practical utility to mankind at large, but it exerts a very ennobling intellectual influence upon the individual mind which pursues it. It carries the thoughts away from the objects immediately around us, and from the events of the passing hour, to the contemplation of the immense distances and magnitudes of the

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What is said of the general benefits which mankind have derived from Astronomy? What beneficial effects does the study of Astronomy produce upon the mind?

heavens, and of the vast periods whose progress and duration she records. At the same time, while it is thus her peculiar province to deal with all that is magnificent and sublime, she trains the minds of her votaries to a precision and accuracy, both of thought and observation, which no other branch of human philosophy pretends to attain. Thus, she connects all that is sublime in extent and grandeur with all that is beautiful in mathematical exactness and precision.

She has doubled the comforts of man, by guiding his commerce; she has taught him mathematics, and led him to the perfection of his nicest arts; she has awakened in his soul the sublimest thoughts and the loftiest aspirations; she has inspired his poetry and kindled his devotion;—so that perhaps the most powerful of all the natural influences which have operated to elevate and ennoble the human species is that which has descended from the stars.

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